

KEITHLEY

Model 2790 SourceMeter[®] Switch System

User's Manual

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Model 2790 SourceMeter[®] Switch System User's Manual

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Manual Print History

The print history shown below lists the printing dates of all Revisions and Addenda created for this manual. The Revision Level letter increases alphabetically as the manual undergoes subsequent updates. Addenda, which are released between Revisions, contain important change information that the user should incorporate immediately into the manual. Addenda are numbered sequentially. When a new Revision is created, all Addenda associated with the previous Revision of the manual are incorporated into the new Revision of the manual. Each new Revision includes a revised copy of this print history page.

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The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with non-hazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by qualified personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the manual for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product may be impaired.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the manual. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, and perform safe installations and repairs of products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are rated Measurement Category I and Measurement Category II, as described in the International Electrotechnical Commission (IEC) Standard IEC 60664. Most measurement, control, and data I/O signals are Measurement Category I and must not be directly connected to mains voltage or to voltage sources with high transient over-voltages. Measurement Category II connections require protection for high transient over-voltages often associated with local AC mains connections. Assume all measurement, control, and data I/O connections are for connection to Category I sources unless otherwise marked or described in the Manual.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30V RMS, 42.4V peak, or 60VDC are present. **A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.**

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 volts, **no conductive part of the circuit may be exposed.**

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, make sure the line cord is connected to a properly grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided, in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting ca-

bles or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

The instrument and accessories must be used in accordance with its specifications and operating instructions or the safety of the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories, as defined in the specifications and operating information, and as shown on the instrument or test fixture panels, or switching card.


When fuses are used in a product, replace with same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as safety earth ground connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a  screw is present, connect it to safety earth ground using the wire recommended in the user documentation.

The  symbol on an instrument indicates that the user should refer to the operating instructions located in the manual.

The  symbol on an instrument shows that it can source or measure 1000 volts or more, including the combined effect of normal and common mode voltages. Use standard safety precautions to avoid personal contact with these voltages.

The  symbol indicates a connection terminal to the equipment frame.

The **WARNING** heading in a manual explains dangers that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in a manual explains hazards that could damage the instrument. Such damage may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits, including the power transformer, test leads, and input jacks, must be purchased from Keithley Instruments. Standard fuses, with applicable national safety approvals, may be used if the rating and type are the same. Other components that are not safety related may be purchased from other suppliers as long as they are equivalent to the original component. (Note that selected parts should be purchased only through Keithley Instruments to maintain accuracy and functionality of the product.) If you are unsure about the applicability of a replacement component, call a Keithley Instruments office for information.

To clean an instrument, use a damp cloth or mild, water based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

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Test System Overview

- **Introduction** — Summarizes the switching modules that are used with the Model 2790 to test inflators. Covers some key features of the Model 2790 and defines/explains technical terms associated with airbag inflators.
- **Model 2790 configurations** — Explains the various mainframe/module combinations available from Keithley.
- **Test system** — Shows a typical test system used to test inflators.
- **Inflator tests** — Explains the three basic tests for inflators: shunt bar, bridgewire, and insulation resistance (HIPOT).

Introduction

When used with one or two switching modules, the Model 2790 can be used to test inflators. With a 7751/7752/7753 module, the Model 2790 can safely measure the resistance of bridgewires and shunt bars. With a Model 7751 or 7753 module, the Model 2790 can use the high voltage method to measure the insulation resistance of an inflator. The 7702 module can be used for ohms testing that requires 20/40 channels of 4-wire/2-wire measurements.

Key features

- **Programmable I-source** — The 7751, 7752, and 7753 modules have a built-in programmable current source (0 to 50mA). This constant current source is used to measure the resistance of bridgewires and shunt bars.
The Model 2790 has a low-ohms math function: $SxIohms$. It calculates (using the programmed current and measured voltage) and displays the resistance (in ohms) of the bridgewire or shunt bar. X is the slot number of the module being used.
- **Programmable V-source** — The 7751 and 7753 modules have a built-in programmable voltage source (50 to 500V) and an I/V converter to measure the insulation resistance of an inflator. Current through the insulator is applied to the I/V converter where it is converted to a voltage that is measured by the Model 2790.
The Model 2790 has a high-ohms math function: $SxVohms$. It calculates (using the programmed V-source voltage and measured I/V converter output voltage) and displays the resistance (in ohms) of the insulation. X is the slot number of the module being used.
- **Safety features** — The Model 2790 has built-in safety features to reduce the possibility of inflator ignition and damage to the module due to excessive current.
 - **Interlock** — The interlock feature of a 7751/7752/7753 module disconnects the sources (I-source and V-source) from the switching matrix. Details on the interlock are provided in [Section 5](#).
 - **Fuses** — Current limiting fuses for the current source of the Model 2790 DMM and the I-source of the 7751/7752/7753 module.
 - **I-source current limiting** — An active, high-speed current limiting circuitry for the I-source of the 7751, 7752, and 7753 modules.
 - **V-source current limiting** — An impedance circuit limits current to <1mA.

Technical terms

The following defines and explains technical terms associated with airbag inflators:

- **Initiator** — Pyro-technic device used to trigger the main gas charge generation action. Sometimes referred to in classic military terms as a “squib”. The term “squib” may be used to refer to the core element of an initiator (explosive coated bridgewire) or to the entire initiator.
- **Airbag inflator** — The gas generating assembly, typically made of steel, containing a stored chemical or pressurized inert gas (or both), and an electrical initiator.
- **Hybrid inflator** — An inflator that uses both pressurized gas and a chemical reaction to generate the gas charge for bag inflation.
- **Airbag or Airbag module** — The fully functional device including initiator, inflator, textile bag and mounting frame (or enclosure).
- **E-check** — Industry standard term for electrical testing of airbag inflators and modules. Consists of two basic resistance measurements:
 - Test continuity of the bridgewire (typically 2 to 3 ohms) using a constant current method (typically 10 to 50mA).
 - HIPOT test — Measure the insulation resistance ($\geq 100\text{M}\Omega$) between the bridgewire and the inflator housing using an applied voltage (typically 500V).
- **HIPOT** — Used in this manual to describe the high resistance measurements made using high voltage. The intent is not to break down the insulator, but to measure the leakage current that flows through the insulator.
- **Body check (contact check)** — Prior to HIPOT testing, connections to the inflator housing must be verified. This is necessary because an open connection would result in a reading that appears to be the resistance of the insulator, but would instead be a high resistance reading that is the result of an open circuit.
- **Shorting clip (shunt bar)** — For handling and transport safety against ESD (electro-static discharge) or other accidental discharge, every inflator module has a spring loaded clip that shorts the initiator/squib pins together when a connector is not installed. The connection cables also include shorting clips since many inflator modules have cables attached when manufactured such that the open end of the cables also have shorting clips. These clips are pneumatically pushed open during E-check testing just after the clips resistance (as a short) is measured.

Model 2790 configurations

Model 2790 test configurations available from Keithley include the following:

2790-H configuration (one 7751 module)

This test system includes a single 7751 module. This module has a programmable 50 to 500V V-source and I/V amplifier for HIPOT testing. It also has a programmable 0 to 50mA constant current I-source to measure the resistance of shunt bars and bridgewires.

2790-HH configuration (two 7751 modules)

This test system includes two 7751 modules. When used with a “left and right” type station, this two-module, high-voltage system allows higher throughput for increased efficiency.

- When used with a “left and right” type station, this two-module, high-voltage system allows two inflators to be tested. It provides higher throughput for increased efficiency. When soaking is required for HIPOT testing, one inflator can be tested while the other inflator is soaking (high voltage applied).
- For a dual inflator, the two high-voltage module system allows parallel “soak and test” of each half.

2790-HL configuration (one 7751 and one 7752 module)

This test system includes a 7751 module and a 7752 module. The high voltage module (7751) can be used for HIPOT testing, while the I-source of the second module (7752) can be used to test other non-inflator type circuitry (i.e., pushbutton switches and resistors) on the steering wheel. The I-source allows accurate resistance measurements up to 100Ω.

2790-L configuration (one 7752 module)

This test system includes a single 7752 module. It is applicable for testing that does not require high voltage HIPOT testing, but still needs the programmable I-source for low ohms testing. Insulation resistance (up to 120MΩ) can be measured using the Ω2 function of the Model 2790.

2790-H/L/A + 7702 configuration (one 7751/7752/7753, one 7702 module)

This test system includes a 7751, 7752, or 7753 module and a 7702 module. The 7702 module can be used for non-inflator related ohms testing that requires 20/40 channels of 4-wire/2-wire measurements. Typical tests using the 7702 module include burn-in/life/QA testing of multi-pin connectors, wiring harnesses, power distribution/fuse centers, switches and relays, and backplanes.

2790-A configuration (one 7753 module)

This test system includes a single 7753 module. This module has a programmable 50 to 500V V-source and I/V amplifier for HIPOT testing. It also has a programmable 0 to 50mA constant current I-source to measure the resistance of shunt bars and bridgewires.

Supplementary system components

For added versatility or as spares, a Model 2790 mainframe, 7751, 7752, 7753, and 7702 modules can be purchased separately. However, this special order may require a longer delivery time and additional handling charges.

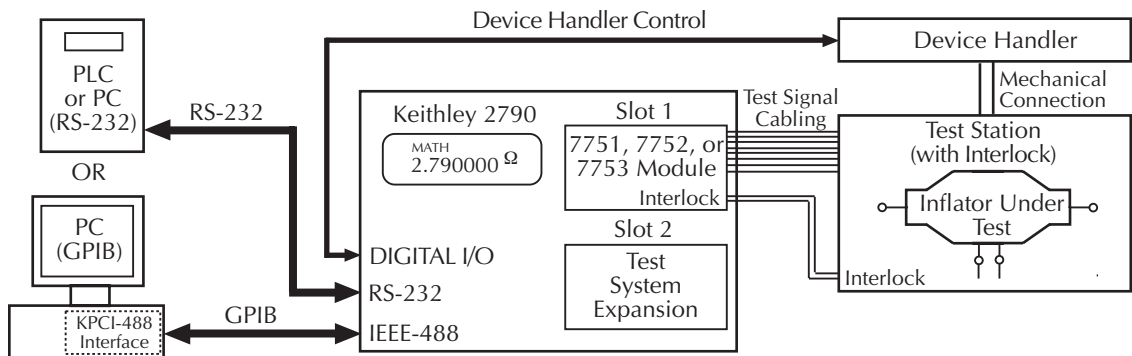
Test system

A typical test system for airbag inflators includes a Model 2790 that is controlled by a PLC or PC, and a device handler/test station for the inflator. The Model 2790 has two slots for switching modules. Modules for testing inflators include the Models 7751, 7752, and 7753. A Model 7702 module can also be used with the Model 2790.

NOTE Only one Model 7753 module can be installed in a Model 2790, and it should be installed in slot 1. The 7753 can be installed in slot 2, but measurement accuracy might be adversely affected because cards are always calibrated in slot 1.

Figure 1-1 shows a typical test system using a programmable logic controller (PLC) or a PC. When using a PLC, communications with Model 2790 are done over the RS-232 interface. When using a PC, communications with the Model 2790 can be provided using the GPIB or RS-232.

Figure 1-1
System connections



Inflator tests

There are three primary tests for an inflator:

- Shunt bar test
- Bridgewire test
- Insulation resistance (HIPOT) test

NOTE ***Interlock** – The three primary tests can only be performed if the interlock of the 7751/7752/7753 module is enabled. With interlock open (disabled), the I-source of the 7751/7752/7753 module and the V-source of the 7751/7753 module are disconnected from the switching module matrix. Details on the interlock are provided in [Section 5](#).*

The following information provides an overview of the three tests that are used to test an inflator. The actual detailed procedures for these tests are provided in [Section 5](#).

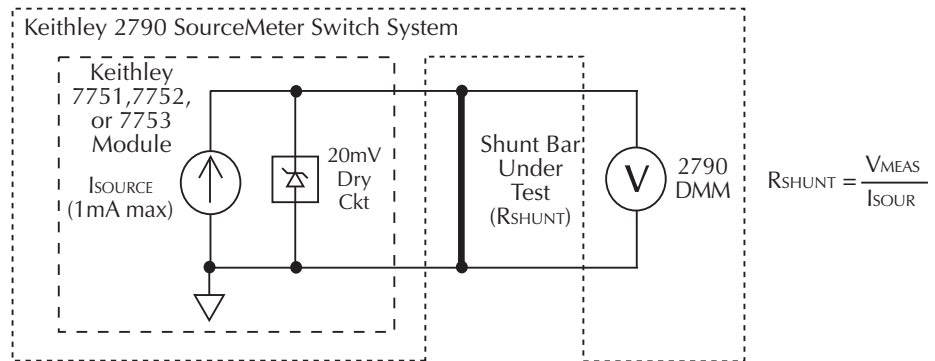
Shunt bar test

NOTE *A shunt bar test is typically tested again after all other inflator tests are completed. As a final test, it verifies that it is safe to install the inflator in a vehicle.*

A shunt bar (shorting clip) is used to short the bridgewire(s) to prevent accidental ignition when handling or installing the inflator. However, an oxide can form between the shunt and the inflator terminals. It is this high-resistance oxide that diminishes the ability of the shunt bar to act as an effective short across the bridgewire(s). Without a good contact short, detonation could occur. The measured resistance of a shunt bar is typically between 10 to 100mΩ.

One method used for the shunt bar test is shown in [Figure 1-2](#). In this case, the dry circuit mode of the 7751/7752/7753 clamps voltage at 20mV (1mA maximum) for the constant test current of the I-source. This low voltage will not pierce the oxide. With the low ohms math function (SxIohms) selected, the R_{SHUNT} reading can be read directly from the display of the Model 2790.

Figure 1-2
Shunt bar testing



NOTE If required, a more accurate resistance measurement of the shunt bar can be achieved by disabling the dry circuit and using a test current of 50mA. An even more accurate resistance measurement can be achieved using the $\Omega 4$ function of the Model 2790. Keep in mind that this is an additional test and does not replace the test using the dry circuit.

NOTE Use this 2-step process to detect the presence of oxide build-up and more accurately measure the resistance of the shunt bar:

1. Test the shunt bar using dry circuit ohms (channel 24 closed) and a test current of 1mA. A resistance $>100m\Omega$ indicates the presence of oxide build-up.
2. Accurately measure shunt bar resistance without dry circuit (channel 24 open) and a test current of 50mA or use the $\Omega 4$ function of the Model 2790. [Section 6](#) explains how to use the $\Omega 4$ function of the Model 2790 with the 7702 or 7751/7752/7753 module.

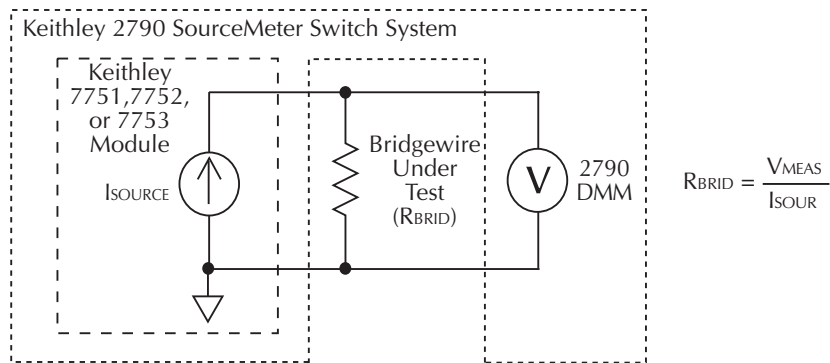
Bridgewire test

The air bag inflator has two terminals connected to a bridgewire, which is coated with a primer that ignites when sufficient current passes through the wire. The bridgewire's resistance is typically from two to three ohms (2Ω being the most common). To avoid unintended ignition, the level of test current applied is generally 50mA or less.

As shown in [Figure 1-3](#), a fixed current is sourced through the bridgewire. The voltage across the bridgewire is then measured by the DMM of the Model 2790.

Figure 1-3

Bridgewire testing



With the low ohms math function selected, the R_{BRID} reading can be read directly from the display of the Model 2790.

I-source readback — Before performing the bridgewire test, you can verify the actual current flowing in the test circuit by using the I-source readback circuit.

NOTE A more accurate ohms reading can be achieved using the $\Omega 4$ function of the Model 2790 (1mA fixed). See [Section 6](#) for details.

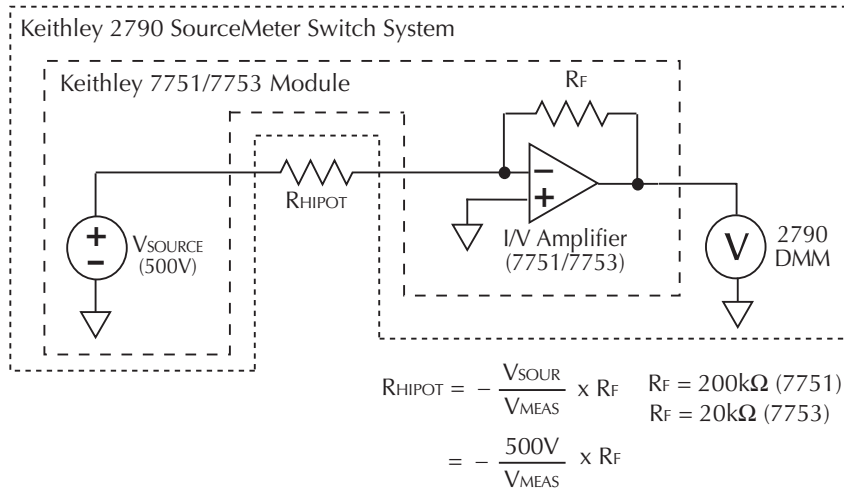
Insulation resistance (HIPOT) test (7751 and 7753 only)

WARNING The Models 7751 and 7753 are provided with outputs that are potentially hazardous if not connected properly. It is the responsibility of the customer to operate instruments in a safe manner. Be sure to read and follow all installation and operating instructions before attempting to use the 7751/7753 HIPOT function.

The leakage resistance (R_{HIPOT}) between each of the initiators and the housing must be verified. As shown in Figure 1-4, this is performed by applying a voltage, typically 500V, between the bridgewire and the housing. The resultant test circuit current is applied to an I/V amplifier, where it is converted to a voltage. This voltage is then measured by the DMM of the Model 2790.

NOTE If not using a 7751/7753 module in your test system, resistance up to $120\text{M}\Omega$ can be measured using the Ω function of the Model 2790.

Figure 1-4
HIPOT testing (7751/7753)



With the high ohms math function (SxVohms) selected, the R_{HIPOT} reading can be read directly from the display of the Model 2790.

Before measuring R_{HIPOT} , there are a couple of preliminary verification tests that should be performed first:

- **Contact checks** — To properly perform the HIPOT test, contact must be made to the air bag inflator housing. If good contact is not established, the measured high resistance will not represent the isolation resistance. Contact is checked by performing continuity checks through the V-source test leads and the connection points. The resistance reading for a contact should be less than 20 ohms (depending on cabling).
- **V-source readback** — Before performing the HIPOT test, the output voltage of the V-source should be verified. The V-source readback circuit allows you to directly measure the output voltage using the DMM of the Model 2790.

2

Keithley 7751, 7752, and 7753

Switching Modules

- **Card configuration** — Provides the simplified schematic of the Keithley 7751, 7752, and 7753 switching modules. Summarizes the individual components of the modules.
- **Setting source output levels** — Explains how to set the output levels for the I-source (7751/7752/7753) and V-source (7751/7753).
- **Math** — Covers the ohms math functions used to calculate low resistance when using the I-source of the 7751/7752/7753, and high resistance when using the V-source and I/V amplifier of the 7751/7753 module.
- **Opening and closing channels** — Explains how to open and close channels for the 7751, 7752, and 7753 modules.
- **Viewing closed channels** — Explains how to display closed channels on the Model 2790.
- **Open interlock errors** — Explains the errors associated with an open interlock.
- **Cable discharge circuit (7751 and 7753)** — Explains the cable discharge circuit. It dissipates voltage at the input channels. This unwanted voltage could ignite the inflator.
- **Connection log** — Use to record connection information.
- **Using memory patterns** — Describes the memory patterns feature, which can be used to simplify repetitive test procedures.

NOTE *Module wiring and installation into the mainframe of the Model 2790 is covered in [Section 4](#).*

Details on using the Keithley 7751, 7752, 7753 modules to test inflators are provided in [Section 5](#).

The edit keys (left, right, up, and down arrow keys) are used to display menu items and output levels. With the desired menu item or output level displayed, it is selected by pressing ENTER.

For remote programming, the <clist> parameter is used as follows:

<clist> = (@SCH)

where: S = Mainframe slot number (1 or 2)

CH = Switching module channel number of source (2 digits)

Examples: (@101) = Slot 1, Channel 1

(@101, 114, 118) = Slot 1, Channels 1, 14, and 18

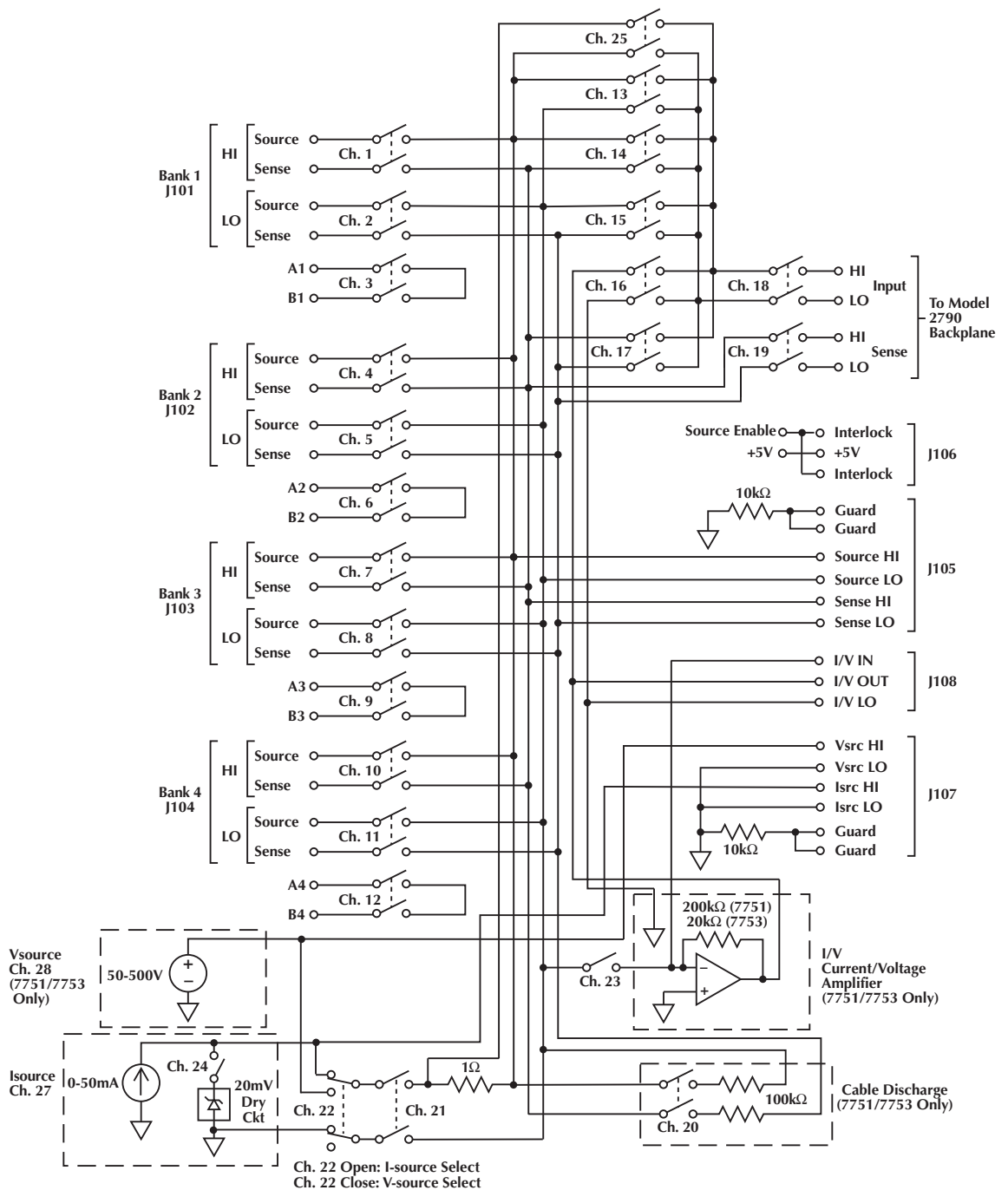
Card configuration

CAUTION **External energy sources should never be applied directly to a 7751, 7752, or 7753 module for any reason. Damage to the module and any connected devices under test can result due to the application of improperly selected or performing external energy sources.**

The simplified schematic for the 7751, 7752, and 7753 is provided in [Figure 2-1](#).

- **Channels 1-12** — Input channels for DUT (inflator).
- **Channels 13-19 and 25** — Routes test signals to backplane of Model 2790.
- **Channels 20-24, 27, and 28** — Control individual components of the 7751/7752/7753.

Figure 2-1
Simplified schematic of Keithley 7751, 7752, and 7753 switching modules



I-source – channels 21, 22, 24, and 27

The programmable I-source (0 to 50mA) is used as the test current to measure low resistance (inflator bridgewires and shunt bars).

- The I-source is designated as channel 27.
- Opening channel 22 selects the I-source.
- Closing channel 21 connects the I-source.
- Closing channel 24 connects the dry circuit clamp for the shunt bar test (20mV, 1mA limit).

NOTE “Ohms specification calculations” in Appendix A explains how to determine the accuracy specification for source levels not specified in the “7751/7752/7753 Source/Switch Module Specifications” sheet.

V-source and I/V amplifier (7751/7753 only) – channels 21, 22, 23, 28

The programmable voltage source (50 to 500V) and I/V amplifier are used to measure high resistance (insulation resistance of an inflator).

- The V-source is designated as channel 28.
- Closing channel 22 selects the V-source.
- Closing channel 21 connects the V-source.
- Closing channel 23 connects the I/V amplifier.

WARNING Do not connect V-source Hi to earth ground. The 7751/7752/7753 module uses a floating ground. This floating ground is not connected to safety earth ground. Not only will it create a shock hazard by floating up to 500V, it will also effectively connect a 1nF capacitor across the V-source, providing energy storage that could ignite an airbag under fault conditions.

NOTE “Ohms specification calculations” in Appendix A explains how to determine the accuracy specification for source levels not specified in the “7751/7752/7753 Source/Switch Module Specifications” sheet.

Cable discharge (7751/7753 only) – channel 20

A cable discharge circuit is used to dissipate charge build-up on the inputs to prevent accidental ignition of the inflator. For details, see “Cable discharge circuit”.

- Closing channel 20 discharges voltage on the input channels.

Source readback – channels 13 and 25

The actual output of the selected source can be verified by using source readback, which routes the selected source back to the DMM of the 2790 for measurement. I-source and V-source readback are explained in [Section 5](#).

- Opening channel 22 and closing channels 21, 25, and 18 connects the I-source sense resistor to the DMM of the Model 2790.
- Closing channels 22, 21, 13, and 18 connects the V-source to the DMM of the Model 2790.

Interlock – J106

A 7751/7752/7753 module has an interlock to disconnect its I-source and V-source from the rest of the switch matrix. In order to use the module sources, interlock must be enabled. The interlock switch of a test station is connected to the J106 terminals of the module. When the interlock switch is open (i.e., safety shield open), the sources cannot be connected to the switch matrix. Details on interlock are provided in [Section 5](#).

NOTE The Interlock switch does not affect the output of J107. Voltage can still be present at those terminals even if the interlock is disabled. See “General purpose terminal blocks – J105, J107, and J108” for additional details.

General purpose terminal blocks – J105, J107, and J108

There are quick-disconnect terminal blocks available to the user to provide access to various switching module components. These are provided for general purpose test applications that are not necessarily related to airbags.

J105 (matrix backplane and guard)

The backplane terminals provide access to the relay matrix backplane. The matrix backplane is the primary “artery” for signal routing through the module.

The guard terminals are typically used for shielding when using the V-source and I/V converter for high ohms measurements. Guard connections are explained in [Section 4](#).

J107 (source outputs and guard)

The I-source and V-source (7751/7753) are always on and can be accessed by the user at J107. The programmed output is routed to these terminals.

The guard terminals are typically used for shielding when using the V-source and I/V converter for high ohms measurements. Guard connections are explained in [Section 4](#).

J108 (I/V converter)

The user also has access to the input, output, and ground of the I/V converter at J108.

Safety warnings

WARNING Integrated safety features protect the 7751/7752/7753 module from its built-in I-source and V-source. However, if an external source (such as the 12V car bus) is connected to the front panel inputs of the Model 2790 or through a 7702 module, these safety features are compromised, creating the very real possibility of igniting the airbag. Incorrect channel closures in the test system could inadvertently apply the external source to the inflator and ignite it. Damage to the 7751/7752/7753 module may also occur if an external source is connected to it.

WARNING Since the Model 2790 system is not an intrinsically safe device, it is the responsibility of the user to ensure that external protection be provided, either by an inherently safe electrical barrier and/or a safety barrier around the DUT or airbag, to prevent injury in case of detonation.

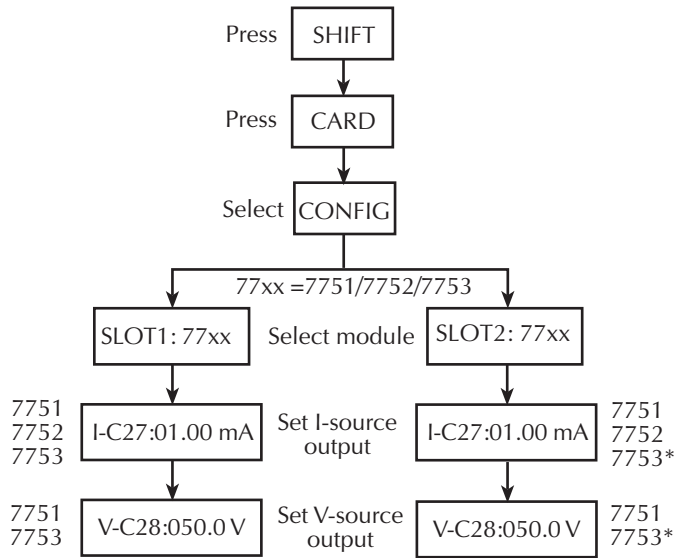
Setting source output levels

I-source and V-source (7751/7753) output levels are set from the CONFIG item of the CARD menu. The menu structure, shown in [Figure 2-2](#), is accessed by pressing and releasing SHIFT and then pressing CARD.

- I-source — Set output from 0 to 50mA. In the menu structure, the I-source is designated as channel 27. The default setting is 1mA.
- V-source (7751/7753 only) — Set output from 50 to 500V. In the menu structure, the V-source is designated as channel 28. The default setting is 50V.

NOTE When using the V-source as an independent source, limit 7751 output current to 50 μ A or 7753 output current to 500 μ A to achieve rated accuracy. Typical short circuit current is <1mA.

Figure 2-2
Setting I-source and V-source output levels



* 7753 should be installed in slot 1 for rated accuracy.

Remote programming

As shown in [Table 2-1](#), the amplitude command is used to set the outputs of the sources. Notice that the channel number of the V-source (28) and I-source (27) must be included in the command string.

Table 2-1

Commands to set amplitude for V-source and I-source

Commands	Description	Default
SOURce:VOLTage[:LEVel][:IMMediate] [:AMPLitude] <NRf>, <clist>	Set V-source output; 50 to 500 (V). <clist> = (@128) Slot 1 = (@228) Slot 2	50V
[:AMPLitude]? <clist>	Query V-source output level.	
SOURce:CURREnt[:LEVel][:IMMediate] [:AMPLitude] <NRf>, <clist>	Set I-source output; 0 to 50 (mA). <clist> = (@127) Slot 1 = (@227) Slot 2	0.001A
[:AMPLitude]? <clist>	Query I-source output level.	

Note: Selecting an ohms calculation enables source tracking. Selecting any other math function disables source tracking.

Math

There is a shortcut math function to calculate low resistance when using the I-source of a 7751/7752/7753 module, and one to calculate high resistance when using the V-source and I/V amplifier of a 7751/7753 module.

Low ohms calculation (SxIohms)

- SxIohms – Calculates and displays low resistance reading for 7751/7752/7753 module in slot x (where x =1 or 2).

This ohms function is a shortcut for the $mX+b$ calculation. When selected, the following “m” and “b” factors are used:

$$m = 1 / I_{\text{SOUR}}$$
$$b = 0$$

$$\begin{aligned}\text{Calculation: } R &= mX + b \\ &= (1 / I_{\text{SOUR}}) \times V_{\text{MEAS}} + 0 \\ &= V_{\text{MEAS}} / I_{\text{SOUR}}\end{aligned}$$

where: I_{SOUR} is the programmed current level of the I-source of the 7751, 7752, or 7753.

$1 / I_{\text{SOUR}}$ is the “m” factor for the calculation ($mX+b$).

V_{MEAS} is the voltage measured by the DMM of the Model 2790. It is the “X” variable for the calculation ($mX+b$).

When the SxIohms calculation is selected, the Model 2790 measures voltage (X) and calculates $mX+b$ using the above factors. The displayed reading will be in ohms (Ω). This selection also sets DMM to DCV, 1V range.

NOTE SxIohms cannot be selected if the I-source is set to 0mA. Since “m” = $1 / I_{\text{SOUR}}$ dividing 1 by 0 would result in an erroneous reading (positive infinity).

When using the low ohms calculation, the highest DCV measurement range that can be selected is 1V. Attempting to select a higher range will cause error -222 (Parameter out of range). Attempting to turn Autoranging on generates error -221 “Settings conflict” over the GPIB or a “NO AUTORANGE” message on the display if done from the front panel AUTO key.

High ohms calculation (SxVohms)

- SxVohms – Calculates and displays the high resistance reading for the 7751/7753 module in slot x (where x =1 or 2).

This ohms function is a shortcut for the $m/X+b$ calculation. When selected, the following “m” and “b” factors are used:

$$m = -200,000 \times V_{\text{SOUR}} \text{ (7751)}$$

$$m = -20,000 \times V_{\text{SOUR}} \text{ (7753)}$$

$$b = 0$$

$$\begin{aligned} \text{7751 calculation: } R &= m/X + b \\ &= (-200,000 \times V_{\text{SOUR}}) / V_{\text{MEAS}} + 0 \\ &= -V_{\text{SOUR}} / V_{\text{MEAS}} \times 200,000 \end{aligned}$$

$$\begin{aligned} \text{7753 calculation: } R &= m/X + b \\ &= (-20,000 \times V_{\text{SOUR}}) / V_{\text{MEAS}} + 0 \\ &= -V_{\text{SOUR}} / V_{\text{MEAS}} \times 20,000 \end{aligned}$$

where: V_{SOUR} is the programmed voltage level of the V-source of the 7751/7753.

For the 7751, $(-200,000 \times V_{\text{SOUR}})$ is the “m” factor for the calculation $(m/X+b)$. 200,000 is the value of the feedback resistor (R_F) for the I/V amplifier ($R_F = 200k\Omega$).

For the 7753, $(-20,000 \times V_{\text{SOUR}})$ is the “m” factor for the calculation $(m/X+b)$. 20,000 is the value of the feedback resistor (R_F) for the I/V amplifier ($R_F = 20k\Omega$).

V_{MEAS} is the output voltage of the V/I amplifier measured by the DMM of the Model 2790. It is the “X” variable for the calculation $(m/X+b)$.

When the SxVohms calculation is selected, the Model 2790 measures voltage (X) and calculates $m/X+b$ using the above factors. The displayed reading will be in ohms (Ω). This selection also sets DMM to DCV, 10V range. Note that the V_{MEAS} reading will be negative (-). Because the output of the V/I amplifier is inverted, the negative value of “m” will cause the ohms reading to be displayed as a positive value.

When using the high ohms calculation (SxVohms), the highest DCV measurement range that can be selected is 10V. Attempting to select a higher range will cause error -222 (Parameter out of range).

If $V > -10mV$, an overflow will occur. If $V < -12V$, an underflow will occur.

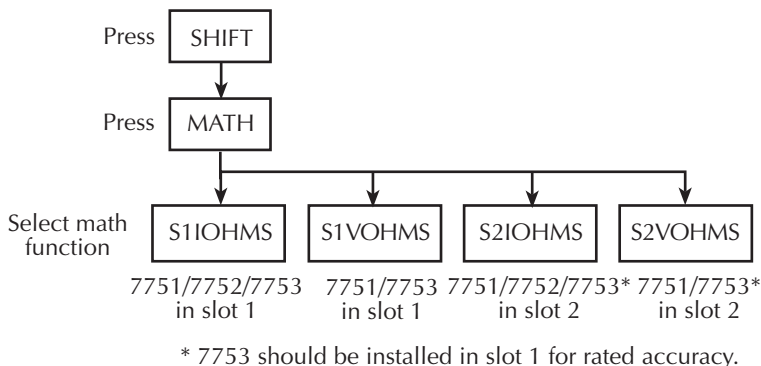
Attempting to turn Autoranging on generates error -221 “Settings conflict” over the GPIB or a “NO AUTORANGE” message on the display if done from the front panel AUTO key.

NOTE Readings for both the 7751 and 7753 modules will overflow when the I/V output is greater than -9mV and underflow when the I/V output is less than -12V.

Front panel operation

An ohms math function is enabled from the MATH menu, which is accessed by pressing and releasing SHIFT and then MATH (see [Figure 2-3](#)). Note that an ohms math function is only available in the menu if the associated 7751, 7752, or 7753 module is installed.

Figure 2-3
Enabling ohms math function



Remote programming

As shown in [Table 2-2](#), the `:CALC:FORMat` command is used to select an ohms math function. Notice that the math setting can be global to all qualified channels or set on a per-channel basis by using the `<clist>` parameter.

NOTE With an ohms math function selected, the Model 2790 is actually measuring DCV. Therefore, if you send `SENS1:FUNC?` to query the selected function, it will return `"VOLT:DC"`.

Source tracking

The Model 2790 provides source tracking to ensure that the most recently set source amplitude is used in the selected ohms calculation. If the source output level changes, the “m” constant for the calculation will change accordingly.

Source tracking is enabled automatically when the desired ohms function is selected. No other actions are required by the user.

However, if desired, source tracking can be disabled or the source that is being tracked can be changed. The `:TRACK` and `:SOURCE` commands are listed in [Table 2-2](#).

Table 2-2

Commands to select ohms calculations

Commands	Description	Default
CALCulate[1]:FORMat <name>	Select math function: NONE, MXB, PERCent, RECiprocal, S1Iohms, S1Vohms, S2Iohms, S2Vohms.	PERC
CALCulate[1]:FORMat?	Query selected math format.	
CALCulate[1]:STATe 	Enable or disable math calculation.	
CALCulate[1]:STATe?	Query state of selected math calculation.	
CALCulate[1]:DATA[:LATest]?	Return last result of calculation.	
CALCulate[1]:DATA:FRESH?	Return last “fresh” result of calculation.	
<i>The following commands are set automatically when an ohms math function (SxIohms or SxVohms) is selected using the :FORMat command. No further actions are required by the user.</i>		
CALCulate[1]:KMATH:MMFactor:TRACk 	Enable or disable source tracking ¹ .	OFF
CALCulate[1]:KMATH:MMFactor:TRACk?	Query state of source tracking.	
CALCulate[1]:KMATH:MMFactor:SOURce <name>	Selects source to be tracked: NONE, S1ISource, S1VSource, S2ISource, S2VSource.	NONE
CALCulate[1]:KMATH:MMFactor:SOURce?	Query source to be tracked.	

¹ Selecting an ohms calculation enables source tracking. Selecting any other math function disables source tracking.

Programming errors

- 222 **Parameter out of range** — Attempted to select a source (:SOURCe command) with a 7702 card installed.
- 241 **Hardware missing** — Attempted to select a source (:SOURCe command) that is not installed.
- +870 **Invalid current error** — Attempted to track an I-source that is set to 0mA. For the low ohms calculation, “m” = $1 / I_{\text{SOUR}}$. Dividing 1 by 0 would result in an erroneous reading (positive infinity).

Opening and closing channels

Multiple channel operations are used to control 7751, 7752, and 7753 channels:

- Only the specified channels are opened or closed. Unspecified channels are not affected.
- Relays to connect signals to the backplane (DMM) of the Model 2790 do not close automatically. You must explicitly close them to perform a measurement. For example, with a DUT connected to channel 1 of a 7751, 7752, or 7753 module, you would have to close channels 1, 14, and 18 to measure it with the Model 2790.
- Closed channels are not displayed by the Model 2790 while in the normal display state. Closed channels can be viewed from the VIEW item of the CARD menu (see “[Viewing closed channels](#)” for details).

To control the appropriate switching module, the slot number must be included with the switching module channel number. The channel assignment is formatted as follows:

SCH where: S is the slot number (1 or 2)
CH is the channel number

Examples: 101 = Slot 1, Channel 1
218 = Slot 2, Channel 18

NOTE *Interlock of the 7751/7752/7753 must be enabled in order to close channel 18, 19, or 21 and open channel 20. See “[Open interlock errors](#)” for errors associated with open interlock and see “[Interlock](#)” in [Section 5](#) for details on using the interlock.*

Front panel operation

As shown in [Figure 2-4](#), the OPEN and CLOSE keys are used to control 7751, 7752, and 7753 channels:

After closing or opening a single channel:

- A message indicating the action (i.e., “101 CLOSED”) will be displayed briefly.
- To close another channel, simply key in the channel number and press ENTER.
- Press EXIT to exit from the open/close menu structure.

NOTE *The edit keys (left, right, up, and down arrow keys) are used to display a channel number. Pressing ENTER opens or closes the channel.*

Viewing closed channels

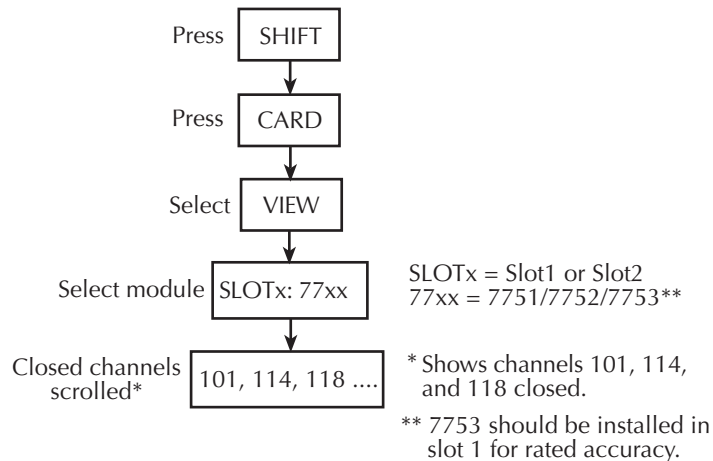
Closed channels can be viewed from the VIEW item of the CARD menu. The menu structure is accessed by pressing and releasing SHIFT and then pressing CARD. As shown in Figure 2-5, the closed channels will scroll across the display:

- The four dots (...) identify the end of the channel string.
- Use the ENTER key to pause and resume scrolling.
- Press EXIT to return to the normal display state.

NOTE For remote programming, closed channels can be identified using `ROUT:MULT:CLOS?` and `ROUT:MULT:CLOS:STAT?` (see Table 2-3).

Figure 2-5

Viewing closed channels



Open interlock errors

The 7751, 7752, and 7753 modules have an interlock. When the interlock is open (disabled), the I-source (7751, 7752, and 7753) and V-source (7751 and 7753) are disconnected from the switching matrix. Details on enabling the interlock are explained in [Section 5](#). The following errors are associated with an open interlock.

Front panel messages:

- INTRLCK OPEN is displayed briefly if you attempt to close channel 18, 19, or 21 with interlock open.
- With the INPUTS switch in the REAR position (in), readings will overflow (OFLO) when the interlock is open.
- In the case of the OFLO readings for open interlock, the IL1 or IL2 message will also be displayed. IL1 is displayed for a slot 1 violation and IL2 is displayed for a slot 2 violation. In the case of errors for both slots, the IL1 message takes precedence.
- Overflowed readings stored in the buffer do not provide interlock status. You cannot tell if the overflow readings are true overflows or the result of open interlock (see “Remote programming errors”, below).

Remote programming errors:

- When an open interlock is first detected, error +860 (slot 1 interlock violation) or +861 (slot 2 interlock violation) occurs. The questionable event register in the status byte can be read to determine which interlock tripped (see Section 11 of the Model 2790 Reference Manual).
- The firmware polls for interlock violations every 50msec. To avoid filling up the error queue, once an error is issued for a given interlock, it must be reset (interlock enabled) before another error event will be issued to the status model for the same interlock.
- Error -224 (parameter error) occurs if you attempt to close channel 18, 19, or 21 with interlock open.
- With interlock open, channel 20 will close and remain closed while interlock is open. ROUT:OPEN:ALL will open all channels except channel 20. ROUT:MULT:OPEN will generate error -224 (parameter error).

Cable discharge circuit (7751 and 7753)

Leakage capacitance exists between signal paths on the switching module and in the test cables. This capacitance can be high enough to store a high voltage charge from the V-source of the 7751/7753 module.

As shown in [Figure 2-6](#), capacitance exists between the source terminals (C_{SO}) and the sense terminals (C_{SE}). These capacitors can be charged by the V-source of the 7751/7753 module during the HIPOT test. This unwanted voltage charge could ignite the inflator if it is connected to a bridgewire.

To prevent a high voltage charge from appearing across the inflator, a discharge circuit is used. As shown in [Figure 2-6](#), channel 20 is closed to provide discharge paths through 100k Ω resistors.

In general, the discharge circuit is controlled as follows:

- When the interlock opens, channel 20 closes to discharge the capacitors. Channel 20 remains closed as long as interlock remains open (see “[Interlock](#)” in [Section 5](#) for details).
- Opening channel 22 closes channel 20 for approximately 5msec to discharge the capacitors. Opening channel 22 selects the I-source (V-source disconnects from rest of module and DUT).

In general, with the test cables connected to the module and the input channels (i.e., 1 and 2) closed, the following sequence should be used to properly perform cable discharge:

1. Open channel 21 to disconnect the V-source and I-source from the input.
2. Open channel 22 to perform cable discharge.

NOTE *If channel 22 is already open, performing the `MULT:OPEN` operation will not close channel 20 to perform cable discharge. However, the `OPEN:ALL` operation will perform cable discharge.*

When the `OPEN:ALL` operation is performed, the following sequence of actions occur:

- 1) *Opens channel 21 to disconnect all sources.*
- 2) *Opens channel 22.*
- 3) *Closes channel 20 for 5msec to perform cable discharge.*
- 4) *Opens all channels.*

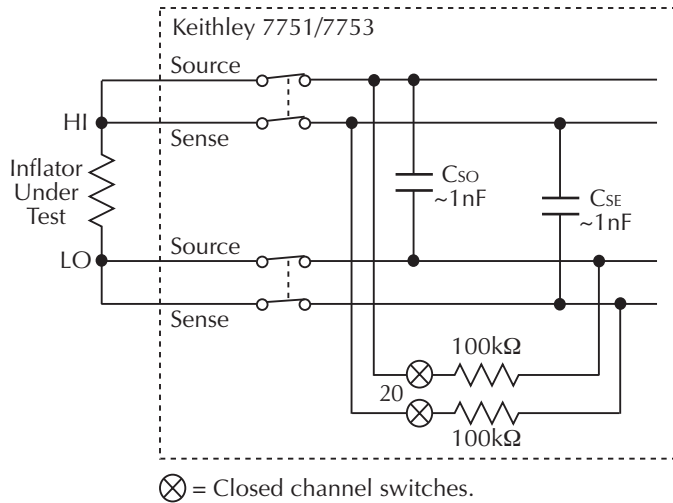
NOTE *In [Section 5](#), the test procedure for HIPOT uses the `OPEN:ALL` operation to perform cable discharge (see steps 7 and 11 in [Table 5-6](#)).*

Manual cable discharge

The discharge circuit can also be activated manually at any time by closing channel 20 of the 7751/7753 module. Typically, manual discharge is used when a discharge time $>5\text{msec}$ is desired.

Figure 2-6

Cable discharge circuit



Connection log

Make a copy of [Table 2-4](#) and affix it to the cover of the 7751/7752/7753 module. Use it to record connection information and channel descriptions as needed.

Table 2-4

Connection log Model 7751/7752/7753

Bank	Channel	Color	Description
Bank 1	CH1 (HI)	Source	
		Sense	
	CH2 (LO)	Source	
		Sense	
	CH3	A1	
		B1	
Bank 2	CH4 (HI)	Source	
		Sense	
	CH5 (LO)	Source	
		Sense	
	CH6	A2	
		B2	
Bank 3	CH7 (HI)	Source	
		Sense	
	CH8 (LO)	Source	
		Sense	
	CH9	A3	
		B3	
Bank 4	CH10 (HI)	Source	
		Sense	
	CH11 (LO)	Source	
		Sense	
	CH12	A4	
		B4	

Using memory patterns

Firmware revision level

Memory patterns are supported in Model 2790 units with firmware A04 and higher. The firmware revision level is displayed as part of the power-up cycle.

Overview

Most Model 7751/7752/7753 tests follow the same basic procedure: select a source and set its level, configure the Model 2790 measurement, close the necessary relays, and take a reading. Memory Patterns simplify this process, allowing you to store combinations of multiple closed channels, source settings, and DMM measurement configurations in nonvolatile memory. Up to 40 such Memory Patterns, designated M1 through M40, can be stored. There is also memory pattern M0, which is defined as an “all-open” pattern. Recalling M0 opens all channels and resets all sources to their factory default values. Similar to closing one 7702 channel and taking a reading, you can recall an individual Memory Pattern to close multiple channels and take a reading. More importantly, you can include Memory Patterns in a scan list and cause the Model 2790 to automatically scan through the specified memory locations. As each memory pattern is scanned, the sources and DMM are configured appropriately, the specified group of channels is closed, and a reading is taken. Reading limits can also be assigned to each memory pattern so that during a scan the readings will automatically be inspected for PASS/FAIL conditions. Digital outputs corresponding to these conditions are also available.

NOTE Memory patterns can be used only with the following functions: DC volts, 2-wire ohms, and 4-wire ohms.

Front panel operation

Memory patterns cannot be defined from the front panel, but they can be recalled once defined by remote commands (see below). To recall defined memory patterns from the front panel:

1. Press CLOSE.
2. Use the RANGE ▲ and ▼ keys to select CLOSE: MEMORY, then press ENTER.
3. Use ◀, ▶, ▲, and ▼ to select the memory pattern number (1-40), then press ENTER.

Memory pattern commands

Memory patterns commands are summarized in [Table 2-5](#). See Section 2 of the Model 2790 Reference Manual for details on these commands.

Command	Description
:ROUTe:MEMory[:CHANnels] <n>, <clist>	Create channel pattern for memory <n> (1-40). Note: 7702 channels cannot be included in <clist>.
:ROUTe:MEMory:SOURce:LEVel <n>, <NRf>, <clist>	Assign source values to the channels in <clist> that will be output when memory pattern <n> is executed. (Source channels only: 127, 128, 227, or 228.)
:ROUTe:MEMory:DElay <n>, <NRf>	Assign a variable delay to memory pattern <n>. (Time in seconds after closing channels and setting source values before making measurements.)
:ROUTe:MEMory:RECall <n>	Immediately execute memory pattern <n>.
:ROUTe:MEMory:READ[:STATe] <n>, 	If set to ON, a reading will be collected after the memory pattern has executed (applies to scanning only). *
:ROUTe:MEMory:CLEar <n>	Clear out memory pattern <n>, setting all channels to open and removing all digital and analog channels from this memory pattern.
:ROUTe:MEMory:CLEar:ALL	Clear out all memory patterns.

* You must include at least one measurement channel or a memory pattern that takes a reading (ROUT:MEM:READ:STAT x, ON). Failure to do so results in the scan list being rejected with Error +702, "No measurement channel in scanlist."

Setting up and executing memory patterns

To set up memory patterns, use the following procedure:

1. Program the desired memory pattern locations using the ROUT:MEM commands. Typically, you would set source value(s), define channels to close, and set up delay for each memory location.
2. Define DCV, 2-wire ohms, or 4-wire ohms measurement function(s) for each memory pattern location.

3. Once a location is defined, use the ROUT:MEM:REC command to recall a memory pattern location, then trigger and acquire a reading using READ?
4. After taking the measurement, use ROUT:OPEN ALL to open all channels.

An example that sets up and executes memory location #1 is shown in [Table 2-5](#). See “[Memory patterns test](#)” on page 5-30 for a more detailed example.

Table 2-5

Basic memory pattern example

Command	Description
:ROUT:MEM:CHAN 1,(@108,115,118)	Specify relays to close.
:ROUT:MEM:DEL 1,0	Set memory delay = 0.
:SENS:FUNC 'RES',(@M1)	Select 2-wire ohms measurement function.
:SENS:RES:RANG 100,(@M1)	Select 100Ω fixed measurement range.
:SENS:RES:NPLC 1,(@M1)	Set A/D integration time to 1 power line cycle.
:ROUT:MEM:REC 1	Recall Memory Location 1.
:READ?	Initiate a measurement and request the result.
:ROUT:OPEN:ALL	Open all relays.

Memory pattern command options

All CALCulate, SENSE, and UNIT subsystem commands with a <clist> (channel list) parameter associated with Model 2790 DC volts, 2-wire ohms, and 4-wire ohms measurement functions can include a memory pattern <clist> parameter (@Mn) that allows you to assign those functions to specific memory pattern locations. For example, the following command selects the 2-wire ohms measurement function for memory pattern location #1:

```
SENS:FUNC 'RES', (@M1)
```

Once various attributes are assigned to memory pattern locations, those functions will be executed when those memory pattern locations are recalled, either individually or while scanning.

Memory pattern scanning

To perform scanning with memory patterns, simply include the memory pattern locations in place of channels in the scan list, then set up and trigger a scan in the usual manner. For example, the following command sets up a memory pattern scan for memory locations 1, 3 and 5:

```
ROUT:SCAN (@M1,M3,M5)
```

Memory pattern log

Table 2-6 provides a log for you to record the stored parameters for each memory location.

Table 2-6

Memory pattern log

Memory location	Source level(s)	Delay	Channels	Functions
M1				
M2				
M3				
M4				
M5				
M6				
M7				
M8				
M9				
M10				
M11				
M12				
M13				
M14				
M15				
M16				
M17				
M18				
M19				
M20				
M21				
M22				
M23				
M24				

Table 2-6 (cont.)

Memory pattern log

Memory location	Source level(s)	Delay	Channels	Functions
M25				
M26				
M27				
M28				
M29				
M30				
M31				
M32				
M33				
M34				
M35				
M36				
M37				
M38				
M39				
M40				

Keithley 7702 Switching Module

- **Safety precautions** — Follow these safety precautions before using the 7751/7752/7753 modules with the 7702 module.
- **Using 7751/7753 V-source with 7702 module** — Explains how to use the 7751/7753 V-source with the 7702 module. Includes a test circuit diagram to explain this application.
- **Card configuration** — Provides the simplified schematic of the Keithley 7702 switching module. Summarizes key aspects of the module.
- **Typical connections** — Shows typical module connections for the various measurements. Includes a connection log to record connection information and channel descriptions.
- **Opening and closing 7702 channels** — Explains how to open and close channels for the 7702 module.
- **Viewing closed channels** — Explains how to display closed channels on the Model 2790.

NOTE *Installation of Keithley switching modules in the mainframe of the Model 2790 is covered in [Section 4](#).*

Details on using the Keithley 7702 module are provided in the Model 2790 Reference Manual.

Details on using the ohms functions of the Model 2790 with the 7702 module are provided in [Section 6](#).

The edit keys (left, right, up, and down arrow keys) are used to display menu items and output levels. With the desired menu item or output level displayed, it is selected by pressing ENTER.

For remote programming, the <clist> parameter is used as follows:

<clist> = (@SCH)

where: S = Mainframe slot number (1 or 2)

CH = Switching module channel number of source (2 digits)

Examples: (@201) = Slot 2, Channel 1

(@201, 214, 218) = Slot 2, Channels 1, 14, and 18

(@201:210) = Slot 2, Channels 1 through 10

Safety precautions

In a system to test inflators, a 7702 module may be used with the 7751, 7752, or 7753 module. In a mixed-module configuration like this, the following safety precautions must be understood and taken:

- External energy sources should never be applied directly to a 7751, 7752, or 7753 module for any reason. Damage to the module and any connected devices under test can result due to the application of improperly selected or performing external energy sources.
- Additional precautions should be taken when using the mainframe measurement functions for the 7751/7752/7753 modules and an external source, connected through the Model 7702 switch module. In the case of a single hardware or software configuration error, or in a fault condition, external energy sources can become directly connected to unintended device under test connections. Where this possibility exists, it is the system designer/builder's sole responsibility to ensure, under all such fault conditions, that no hazardous or damaging situations are created.

Card configuration

Unlike the 7751, 7752, and 7753 modules, the 7702 module supports system channel operation. That is, when an input channel is closed, other channels on the module automatically close to connect the input to the backplane (DMM) of the Model 2790.

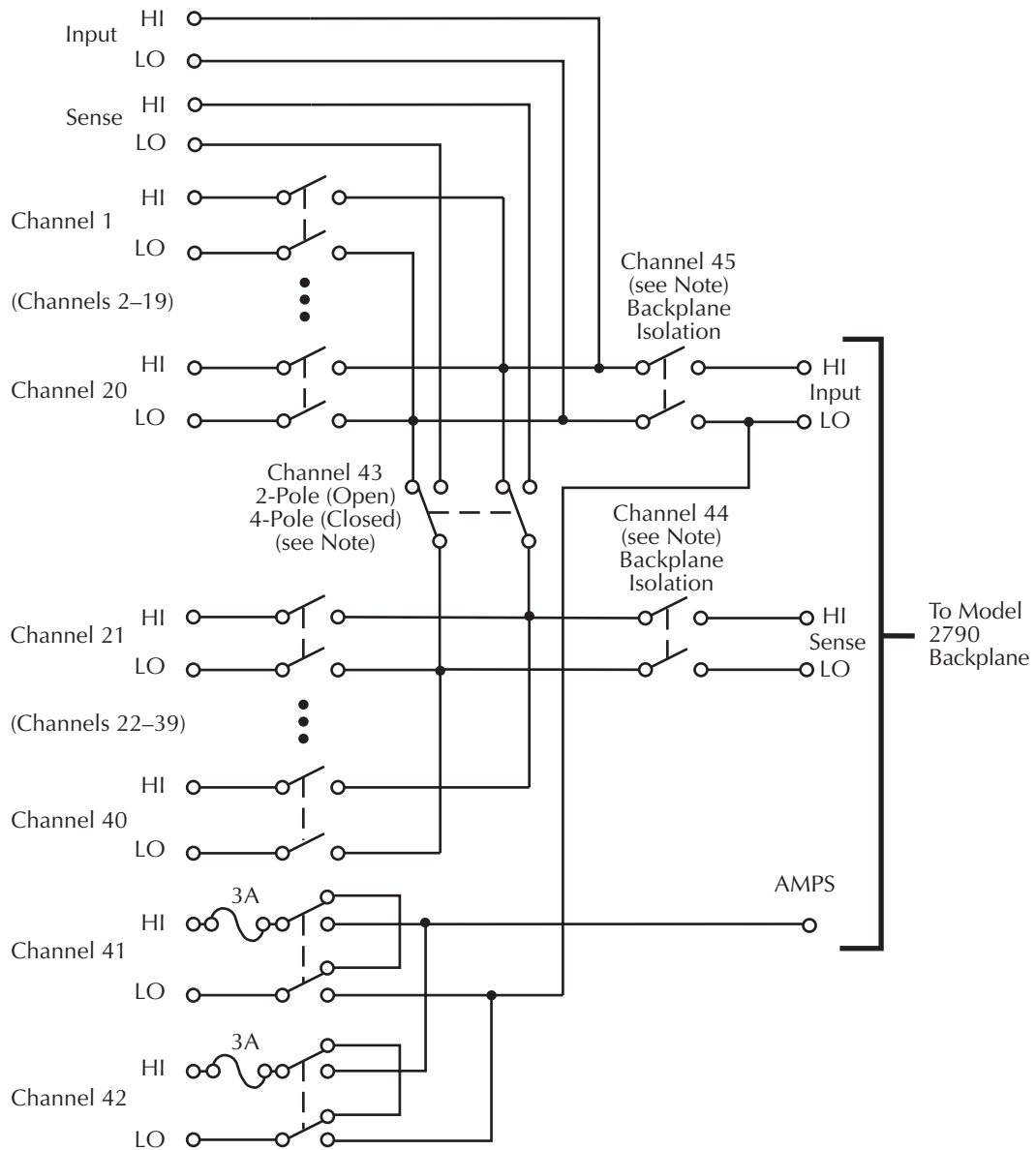
Figure 3-1 is a simplified schematic diagram of the Model 7702 module. As shown, the Model 7702 has channels that are grouped into two banks of twenty channels (forty channels total). Backplane isolation is provided for each bank. The first bank contains channels 1 through 20 while the second bank contains channels 21 through 40. Each channel of the 40-channel multiplexer card is wired with separate inputs for HI/LO providing fully isolated inputs. The Model 7702 also provides two channels of current input, Channels 41 and 42.

Although the Model 7702 relays are the latching type (relays hold their state even after power has been removed), all relay states are set to open a few seconds after either a power cycle or a *RST command is issued.

For a 4-wire function or operation (Ω , RTD TEMP, Ratio, or Channel Average), the channels are paired as follows:

- CH1 and CH21
- CH2 and CH22
- CH3 and CH23
- CH4 and CH24
- CH5 and CH25
- CH6 and CH26
- CH7 and CH27
- CH8 and CH28
- CH9 and CH29
- CH10 and CH30
- CH11 and CH31
- CH12 and CH32
- CH13 and CH33
- CH14 and CH34
- CH15 and CH35
- CH16 and CH36
- CH17 and CH37
- CH18 and CH38
- CH19 and CH39
- CH20 and CH40

Figure 3-1
Simplified schematic of Keithley 7702 switching module



Note: Channels 43–45 in this schematic refer to the designations used for control and not actual available channels.

Channels 43, 44, and 45 can be individually controlled using multiple channel operation (`ROUT:MULT` commands) if the module is not to be connected to the internal DMM.

Typical connections

The following examples show typical 7702 wiring connections for the following types of measurements:

- Ω 2 and thermistor temperature connections, see [Figure 3-2](#).
- Ω 4 and RTD temperature connections, see [Figure 3-3](#).
- Current connections (DCI or ACI), see [Figure 3-4](#).
- Voltage connections (DCV or ACV), see [Figure 3-5](#).

Figure 3-2

Ω 2 and thermistor TEMP connections

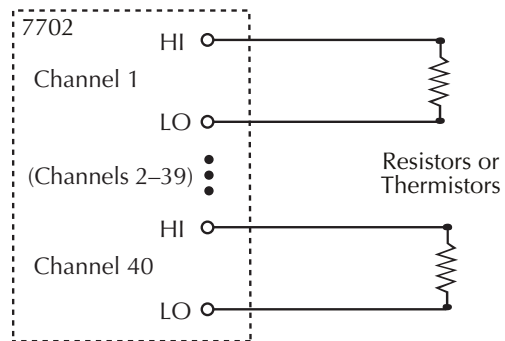
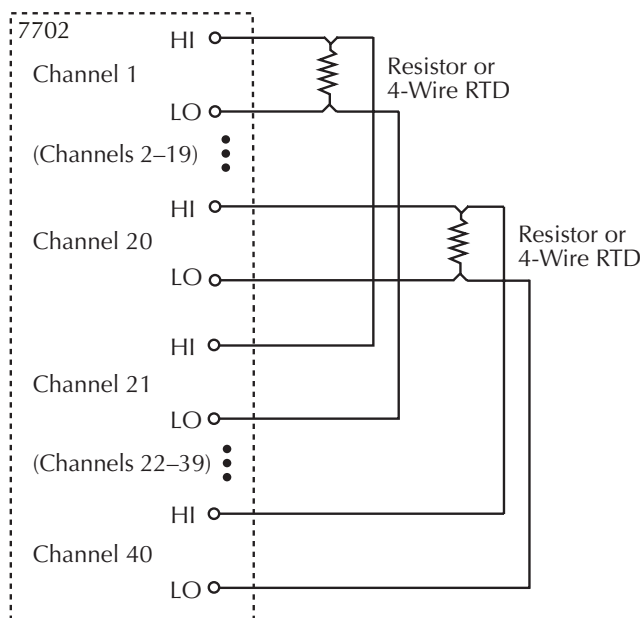


Figure 3-3
 Ω and RTD TEMP connections



NOTE For details on using the 7702 module to make ohms measurements, see [Section 6](#), “Model 2790 DMM Ohms Functions.”

Figure 3-4
Current connections (DCI and ACI)

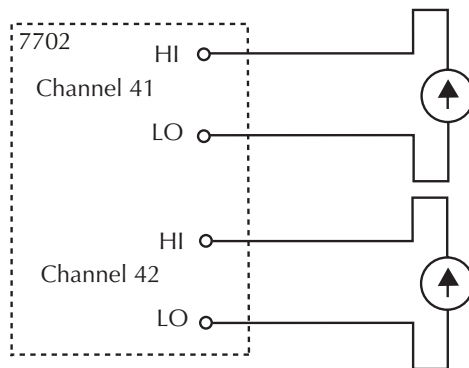
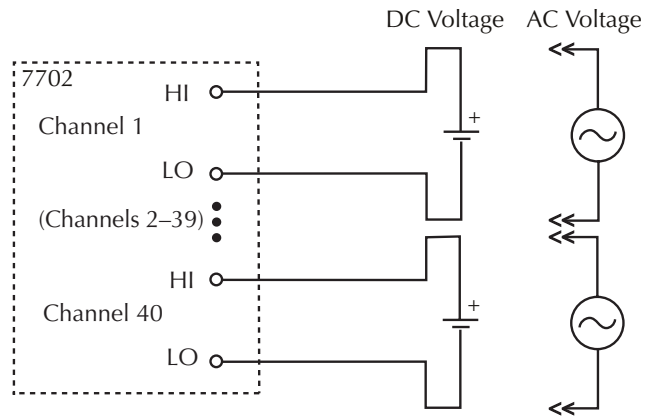


Figure 3-5
Voltage connections (DCV or ACV)



Connection log

Make a copy of [Table 3-1](#) and affix it to the cover of the Model 7702. Use this to record connection information and channel descriptions as needed.

Table 3-1
Connection log Model 7702

Channel	Color	Description	Description	Color	Channel
INPUT	H				
	L				
SENSE	H				
	L				
CH21	H				H CH1
	L				L
CH22	H				H CH2
	L				L
CH23	H				H CH3
	L				L
CH24	H				H CH4
	L				L
CH25	H				H CH5
	L				L
CH26	H				H CH6
	L				L
CH27	H				H CH7
	L				L
CH28	H				H CH8
	L				L
CH29	H				H CH9
	L				L
CH30	H				H CH10
	L				L
CH31	H				H CH11
	L				L
CH32	H				H CH12
	L				L
CH33	H				H CH13
	L				L
CH34	H				H CH14
	L				L
CH35	H				H CH15
	L				L
CH36	H				H CH16
	L				L
CH37	H				H CH17
	L				L
CH38	H				H CH18
	L				L
CH39	H				H CH19
	L				L
CH40	H				H CH20
	L				L
AMPS41	H				H AMPS42
	L				L

Opening and closing 7702 channels

Normally, system channel operation is used to control 7702 input channels.

NOTE *It is not recommended, but multiple channel operation can be used to control a 7702 module. For multiple channel operation, the 7702 module is controlled in basically the same way that a 7751/7752/7753 module is controlled (see [Section 2](#)), except that multiple channel control (:ROUT:MULT) must be used to control the 7702 module. More details on multiple channel operation is provided in [Section 2 of the Model 2790 Reference Manual](#).*

The following points summarize system channel operation. Details on system channel operation for the 7702 module is provided in [Section 2 of the Model 2790 Reference Manual](#).

- When an input channel is closed for a 2-wire function, a backplane isolation channel automatically closes to connect the input to the DMM of Model 2790.
Example: With the $\Omega 2$ function selected, closing channel 1 also closes channel 45.
- When an input channel is closed for a 4-wire function or operation, the two backplane isolation channels and the 2-pole/4-pole relay also close to connect the input to the DMM.
Example: With the $\Omega 4$ function selected, closing channel 1 also closes channel 21 (paired channel), 45 (backplane channels), and 43 (2-pole/4-pole relay).
- While in the normal measurement display state, only the input channel that is closed is displayed on the Model 2790. For a 4-wire operation, the paired input channel is not displayed.
- Only one input channel (and its paired input channel for 4-wire) can be closed at the same time. When you close another input channel, the previous input channel opens.

Channel assignments

To control the appropriate switching module, the slot number must be included with the switching module channel number. The channel assignment is formatted as follows:

SCH where: S is the slot number (1 or 2)
CH is the channel number

Examples: 101 = Slot 1, Channel 1
218 = Slot 2, Channel 18

Front panel operation

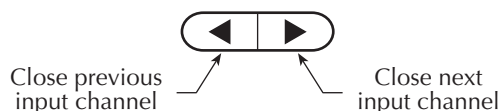
For system channel operation, there are two methods to close an input channel. You can use the ◀ and ▶ keys or the SINGLE option for the CLOSE key. The OPEN:ALL option for the OPEN key opens all channels.

◀ and ▶ keys

These front panel keys (Figure 3-6) can be used to select the next or previous input channel.

Figure 3-6

◀ and ▶ keys



With the first 7702 input channel closed (displayed), pressing the ◀ key opens the closed input channel. With the last 7702 input channel closed (displayed), pressing the ▶ key opens the closed input channel.

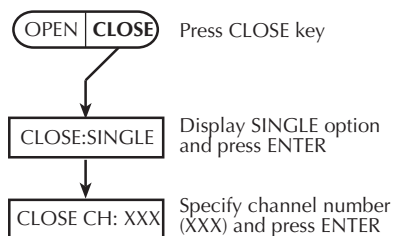
CLOSE key

As shown in Figure 3-7, the SINGLE option of the CLOSE key can be used to close an input channel, while the MULT option can be used to close multiple channels.

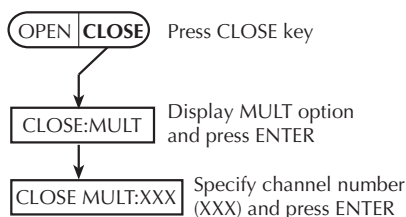
Figure 3-7

CLOSE key

A) Closing a single channel



B) Closing multiple channels

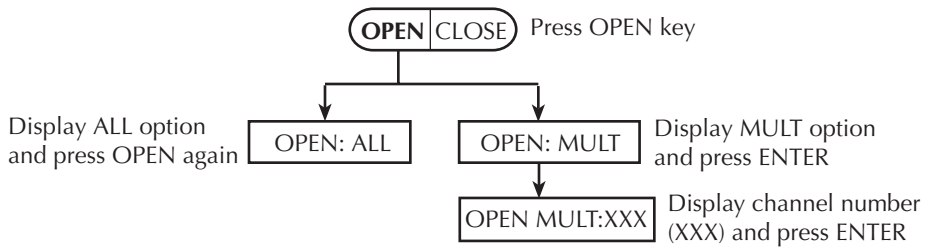


OPEN key

As shown in [Figure 3-8](#), the OPEN:ALL option of the OPEN key opens all channels in the mainframe (both slots), while OPEN:MULT opens multiple selected channels.

NOTE For a 7751/7752/7753 module, the OPEN:ALL operation will not open channel 20 if the interlock is open.

Figure 3-8
OPEN key



Remote programming

The commands to control 7702 channels are listed in [Table 3-2](#).

Table 3-2
Commands to control 7702 module channels

Commands	Description
ROUTe:CLOSE <clist>	Specify one input channel to close.
ROUTe:OPEN <clist>	Open channel specified in list.
ROUTe:OPEN:ALL	Open all channels.
ROUTe:CLOSE?	Return closed channel.
ROUTe:CLOSE:STATe? <clist>	Query channels in specified list; 0 = open, 1 = closed.

Examples: ROUT:OPEN:ALL ‘ Open all channels.
 ROUT:CLOS (@101) ‘ Close 7702 channel 1 in slot 1.
 ROUT:CLOS? ‘ Return closed channel.

Viewing closed channels

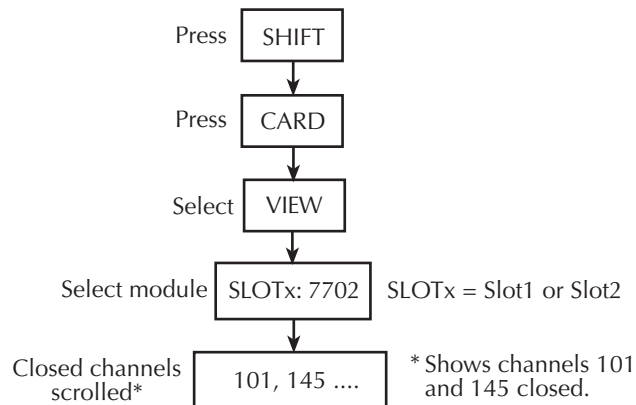
Closed channels can be viewed from the VIEW item of the CARD menu. Closed channels, including backplane channels and 2-pole/4-pole relay, are scrolled across the display of the Model 2790.

The menu structure is accessed by pressing and releasing SHIFT and then pressing CARD. As shown in [Figure 3-9](#), the closed channels will scroll across the display:

- The four dots (...) identify the end of the channel string.
- Use the ENTER key to pause and resume scrolling.
- Press EXIT to return to the normal display state.

NOTE For remote programming, all closed channels can be identified using `ROUT:MULT:CLOS?` and `ROUT:MULT:CLOS:STAT? <clist>`. (See Table 2-2 in the Model 2790 Reference Manual.)

Figure 3-9
Viewing closed channels



Using 7751/7753 V-source with 7702 module

WARNING The 7702 module is designed to handle DC peak voltages up to 300V generated by external and potentially unlimited energy type sources. When the 7702 module is used in conjunction with the 7751/7753 module, it can be used safely up to the full output voltage capability of the 7751/7753 V-source (500V DC peak). This DOES NOT imply that the 7702 module can be used with EXTERNAL SOURCES (i.e., non-7751/7753 derived) above 300V DC peak.

NOTE Although the 7702 module is rated for 300V, it can be used with the 500V output from the 7751/7753 module, due to the extremely low current available from the source. No safety or reliability issues will result from using the 7751/7753 output with the 7702 module if the equipment is used according to the instructions provided.

The V-source of the Model 7751/7753 can be used with the 7702 module. A typical test system is to use the Model 7702 as a dual multiplexer to bias and measure up to 20 DUTs. The V-source of 7751/7753 module powers the DUT, while the DMM of the Model 2790 measures the output of the DUT. To prevent overloading of the V-source, each DUT is powered (and measured) separately.

Figure 3-10 shows the test circuit for this application. The 7751 V-source is connected to the Sense terminals of the 7702 module. DUTs are connected to channels 1 through 20 of the 7751/7753 module. Channels 21 through 40 are used to connect the V-source to each DUT.

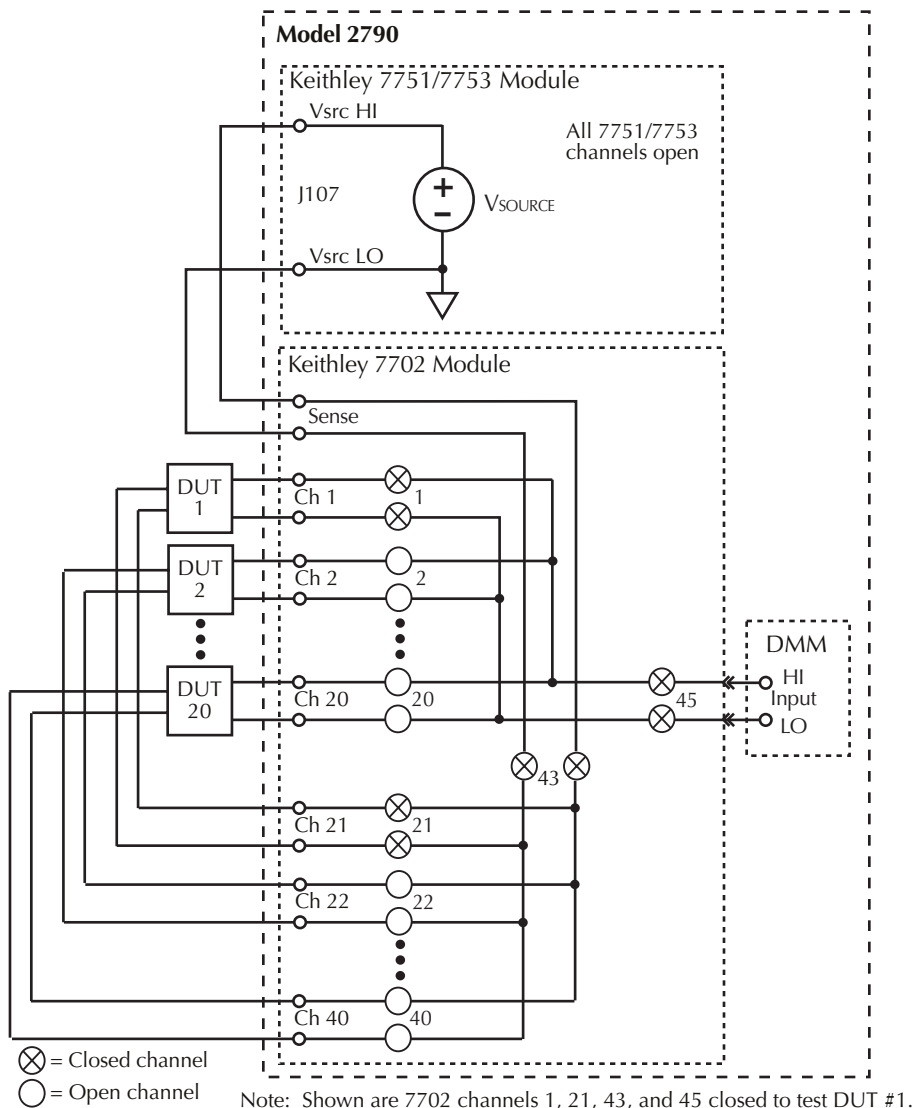
To use the 7702 module as a dual multiplexer, multiple channel operation must be used to control channels for this application. All channels of the 7751/7753 module are to remain open.

NOTE Section 2 (“Setting source output levels”) explains how to set the output of the V-source of the 7751/7753 module.

During the testing process, channels 43 and 45 of the 7702 are to remain closed. To test DUT 1, input channels 1 and 21 are then closed. To test DUT 2, input channels 2 and 22 are closed. DUT 3 through 20 are tested in a similar manner by closing the appropriate pair of input channels. Keep in mind that when testing a DUT, only the two appropriate inputs are closed. All other input channels must be open.

NOTE See “Multiple channel operation - Dual independent multiplexers” in Section 2 of the Model 2790 Reference Manual for details on using the 7702 module as a dual multiplexer. In Figure 2-9 of the reference manual, the 7751/7753 V-source would replace the “External Source”.

Figure 3-10
Using 7751/7753 V-source with 7702 module (dual multiplexer)



4

Switching Module Wiring and Installation

- **Connections and wiring** — Provides the details needed to make connections to the screw terminals of the 7751/7752/7753 and 7702 modules.
- **Switching module installation** — Explains how to install a 7751, 7752, 7753, or 7702 in the Model 2790 mainframe.

Connections and wiring

WARNING The following information is intended for qualified service personnel. Do not make switching module connections unless qualified to do so.

WARNING To prevent electric shock that could result in serious injury or death, adhere to following safety precautions:

- Before removing or installing a switching module in the mainframe, make sure the mainframe is turned off and disconnected from line power.
- Before making or breaking connections to a switching module, make sure power is removed from all external circuitry.
- Do not connect signals that may exceed the maximum specifications of the module. Specifications for the switching modules are provided in Appendix A.
- Do not apply >42V between any terminal (HI or LO) and chassis ground. Do not apply any external sources to the 7751/7752/7753 module.

NOTE 7702 allows measurement of external sources, but use extreme caution, single faults hardware/software could detonate airbag.

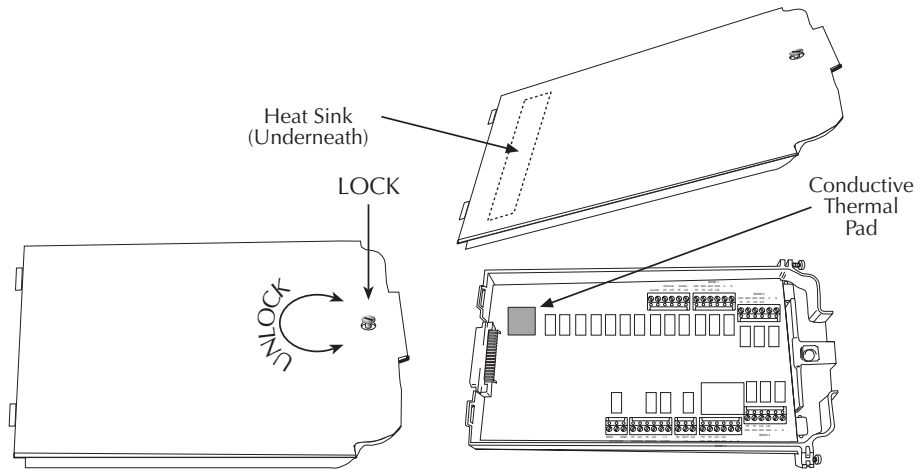
Screw terminals

Screw terminals on the switching modules are used for connection to DUT and external circuitry. The Models 7751, 7752, and 7753 use quick-disconnect terminal blocks. A terminal block can be wired outside the module and then plugged back in.

Figure 4-1 shows how to access the screw terminals on the switching module. Channel designations for the screw terminals are contained in Figure 4-2 (7751/7752/7753) and Figure 4-3 (7702).

CAUTION For the Model 7751/7753, be sure that the thermal pad is not dislodged. Also be sure to use the correct cover with the integral heat sink to assure proper voltage source operation. Note that earlier 7751 modules do not have the pad or heat sink.

Figure 4-1
Screw terminal access



Cabling requirements

General requirements — Cable wires should be mechanically durable, preferably 20AWG or larger with a high voltage insulation, such as rubber or silicon, good for at least 1000V.

It is the responsibility of the user to use the size and type of cable wire that best suits your needs. Keep in mind that Teflon insulated wire performs better in high humidity conditions, but it is not recommended when subjected to mechanical movement, like a device handler.

Recommended cable wire — Belden® 8899 cable wire, which is stranded 18AWG in size, with a thick rubber insulation rated for 5000V working voltage. It is very flexible and mechanically durable.

NOTE *The use of an outer protective cable shield is recommended to prevent damage to the wire insulation. It should preferably have a foil shield tied to earth ground on one end to provide an extra layer of protection in the event that a wire conductor becomes exposed. It will also serve to reduce measurement noise caused by nearby machinery. A recommended cable shield is available from Zippertubing® and covered later in this section.*

Wiring procedure

Use the following procedure to wire a 7751, 7752, 7753, or 7702 module. Make sure to add supplementary insulation around the harness for voltages above 42V peak (see [Figure 4-4](#)).

NOTE *Figure 4-2 and Figure 4-3 show channel identification for the 7751/7752/7753 and 7702 modules. Figure 4-4 shows how to wire a 7751/7752/7753 module. Wiring for the 7702 module is similar.*

WARNING Do not connect 7751/7753 V-source Hi to earth ground. The 7751/7752/7753 module uses a floating ground. This floating ground is not connected to safety earth ground. Not only will it create a shock hazard by floating up to 500V, it will also effectively connect a 1nF capacitor across the V-source, providing energy storage that could ignite an airbag under fault conditions.

WARNING All wiring and supplementary insulation must be rated for the maximum voltage in the system. For example, if 500V is being used in the test system, the module wiring (for both slots) must be rated for at least 500V.

CAUTION For the 7751/7753, be sure not to dislodge the thermal pad on the voltage source. Also be sure to use only the top cover with the integral heat sink to assure proper voltage source operation.

1. Make sure all power is discharged from the switching module.
2. Access the screw terminals (see [Figure 4-1](#)).
3. Using a small flat-blade screwdriver, loosen terminal screws and install wires as desired. [Figure 4-4](#) shows 7751/7752/7753 connections to channels 1 and 2, and the interlock.
4. Route wire along wire-path and secure with cable ties as shown. Note that the wires leading out of the module should be encased in a ground wrap (see “[Zippertubing® shield](#)”).
5. Fill in a copy of the connection log ([Table 2-4](#) for the 7751/7752/7753, and [Table 3-1](#) for the 7702) and affix it to the module cover.
6. Close and lock cover.

Figure 4-2

Model 7751/7752/7753 screw terminal channel designs

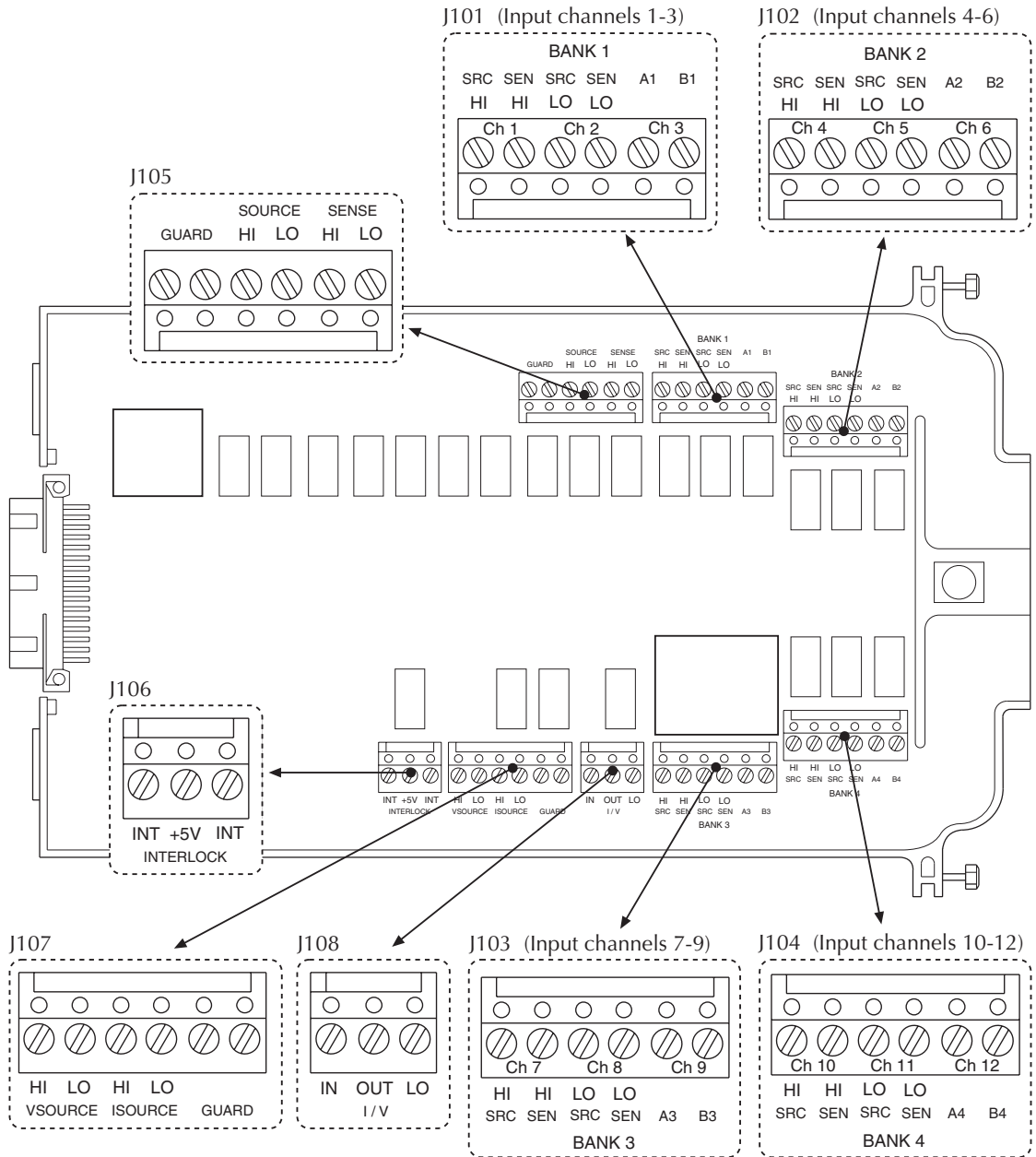


Figure 4-3

Model 7702 screw terminal channel designs

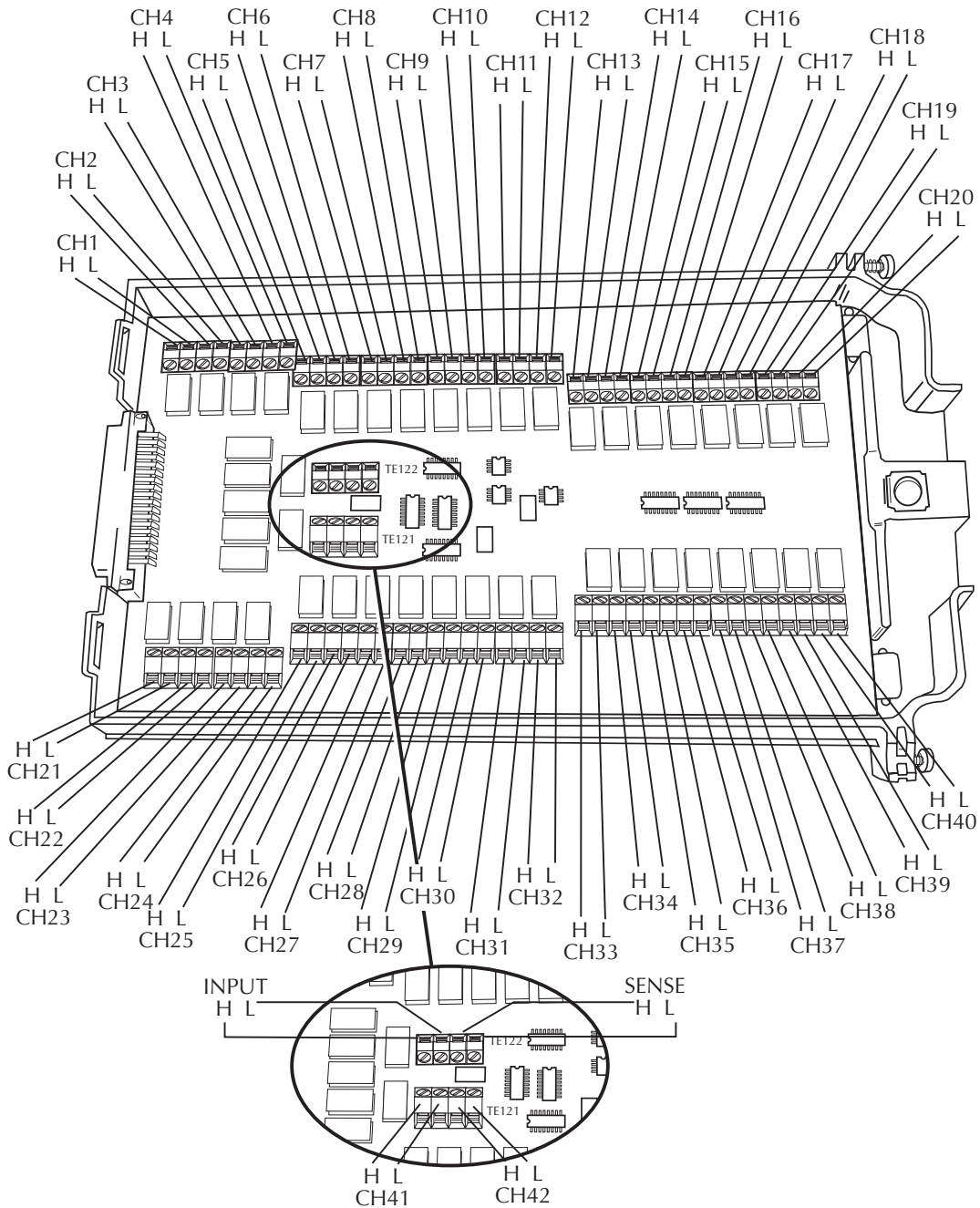
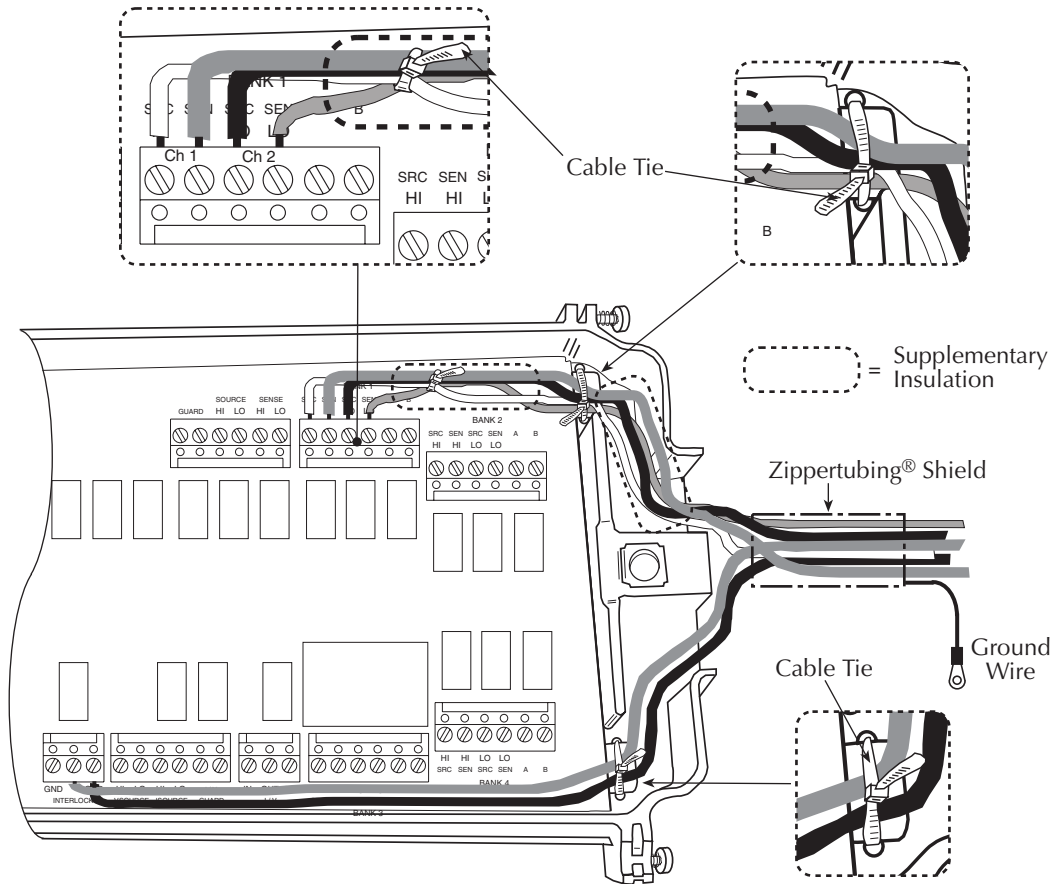


Figure 4-4
Wire dressing (7751/7752/7753)



Zippertubing® shield

A grounded, wrap-around shield for the wiring between the switching module and the test station should be installed. The shield is a grounded metal foil that surrounds the bundle of wires. The foil shield prevents damage to the wire insulation. Grounding the shield to a safety earth ground provides extra protection in case a wire conductor becomes exposed. It also serves to reduce measurement noise caused by EMI from nearby machinery.

A recommended shield is shown in [Figure 4-5](#). It is a Zippertubing® ZTZ-*-SH3 series shield. As shown, the foil side wraps around the cable wires. The shield is then held in place by fastener strips that zip together.

The ground wire of the shield is to be connected to a safety earth ground as shown in [Figure 4-6](#).

Figure 4-5

Zippertubing® shield (ZTZ-*-SH3 series)

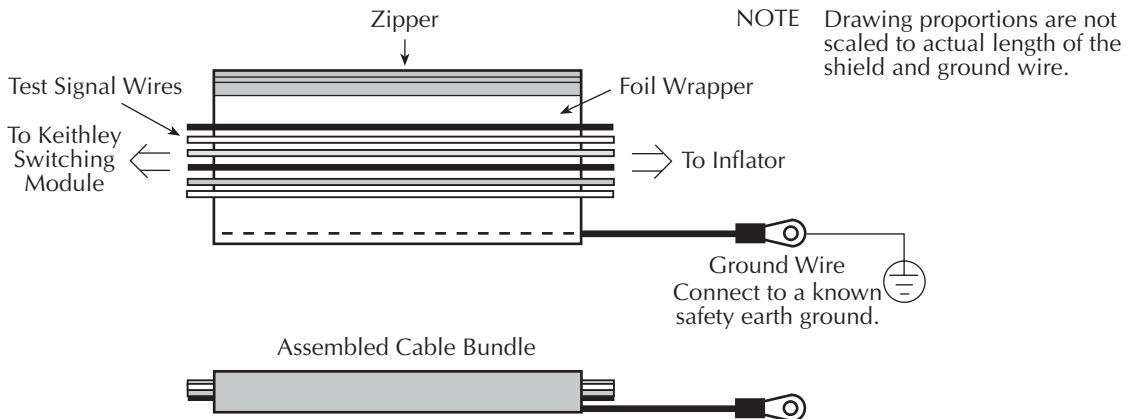
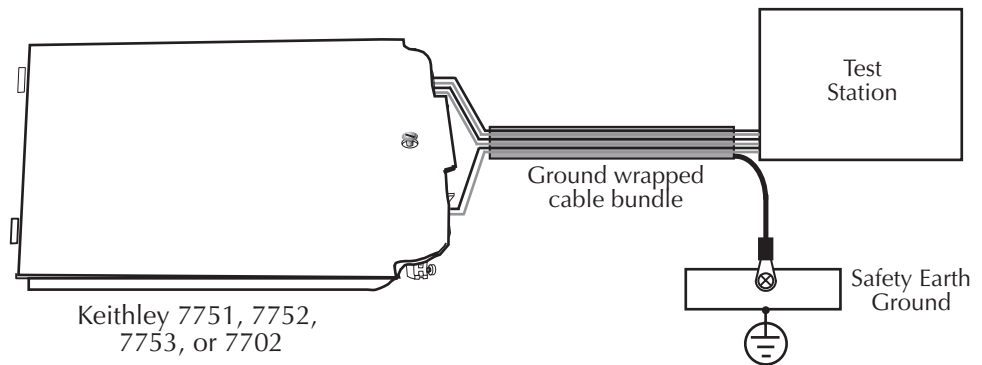


Figure 4-6
Installed Zippertubing® shield



Guarding

NOTE The typical high ohms measurement applications for the 7751/7753 V-source does not require guarding. Guarding only needs to be used for the most demanding, noisy situations, or when measuring $>1G\Omega$ (which is the maximum resistance specified for the 7751/7753).

A second inner shield can be used for high ohms measurements that use the 7751/7753 V-source and I/V converter. This guarded shield may reduce noise and cable leakage that could result in measurement errors.

The guard terminals are available at J105 and J107. Guard is connected to a shield that surrounds the Source Lo and Sense Lo test leads that connect to the housing of the inflator. In [Figure 5-3 \(Section 5\)](#), use the guard shield to surround the two wires that are connected to Bank 3 (J103) of the 7751 module.

This guard shielded wire pair should be positioned inside the main cable bundle whose shield is connected to safety earth ground. The guard shield should be insulated with an outer jacket. A second Zippertubing® shield can be used as the guard shield.

WARNING The guard terminals are connected to the floating ground of the 7751/7752/7753 module. Do not connect V-source Hi to earth ground. If V-source Hi is connected to earth ground, guard could float up to 500V.

WARNING Do not connect V-source Hi to earth ground. The 7751/7752/7753 module uses a floating ground. This floating ground is not connected to safety earth ground. Not only will it create a shock hazard by floating up to 500V, it will also effectively connect a 1nF capacitor across the V-source, providing energy storage that could ignite an airbag under fault conditions.

NOTE For high ohms measurements ($>1G\Omega$), it is recommended that the DUT be connected between two different banks (for example, Bank 1 and Bank 3 as seen in test connection figures) to reduce the possibility of measurement error caused by leakage resistance.

Switching module installation

Module slot considerations

Only one Model 7753 module can be installed in a Model 2790, and it should be installed in slot 1. A 7753 module can be used in slot 2, but measurement accuracy might be adversely affected because cards are always calibrated in slot 1.

Power supply restrictions with the 7753 module

Under some conditions (low line, maximum current draw), two 7753 modules could draw enough power to cause the Model 2790 to reset. To avoid this situation, installed modules are checked at power-up. If a 7753 module is present, the other slot must be empty or populated with a 7702 module.

If this condition is violated (a Model 7753 plus any other 775x module), the Model 2790 will lock up with the message “1 7753 ONLY” displayed, and all annunciators will turn on. In this case, you must remove one module and cycle power to continue.

Installation procedure

A Keithley switching module simply slides into one of two slots in the rear panel of the Model 2790:

1. Turn off the Model 2790 and make sure there is no external power connected to it or the module. External sources should never be used anywhere in the test system to take advantage of the 2790 improvements that reduce the risk of airbag detonation.
2. If a slot cover is installed, remove it and retain for future use.
3. With top cover side up, slide the connector end of the module into the mainframe. Make sure the front edge of the card is in the track for the slot.
4. Push the module all the way in until it mates with the backplane connector of the mainframe.
5. Hand-tighten the two screws that secure the module in the mainframe. Tightening these screws connects the module to chassis ground.

5 Inflator Testing

- **Introduction** — Summarizes the tests used for airbag inflators and provides notes that apply to most tests.
- **Test system** — Shows a typical system connection using a programmable logic controller (PLC) and a PC.
- **Test signal connections** — The four basic system test connection schemes for inflator testing.
- **Interlock** — Covers interlock, which is used to disconnect the sources of the 7751, 7752, and 7753 modules from the switch matrix.
- **Shunt bar test** — Provides the test circuit and procedure to measure the resistance of a shunt bar.
- **Bridgewire tests** — Provides the test circuit and procedure to measure bridgewire resistance of an inflator.
- **Insulation resistance (HIPOT) tests (7751/7753 only)** — Provides the test circuits and procedures to measure the insulation resistance of an inflator. Summarizes cable discharge. Includes tests for contact checks for high voltage connections and V-source readback verification.
- **I-source readback** — Shows how to use the I-source readback circuit to verify the actual current flowing in the test circuit for bridgewire and shunt bar tests.
- **Memory patterns test** — Gives a test example using the memory patterns feature, which can be used to simplify repetitive tests.

Introduction

There are three primary tests for an inflator:

- Shunt bar test
- Bridgewire test
- Insulation resistance (HIPOT) test

This section focuses on performing the inflator tests. Details on the tests are provided in [Section 1](#).

WARNING Since the Model 2790 system is not an intrinsically safe device, it is the responsibility of the user to ensure that external protection be provided, either by an inherently safe electrical barrier and/or a safety barrier around the DUT, or airbag, to prevent injury in case of detonation.

Test procedures

Tables — Test procedures for remote programming and front panel are presented in tables. All test procedures assume the 7751, 7752, or 7753 module is installed in slot 1 of the mainframe.

NOTE Only one Model 7753 can be installed in a Model 2790 and it should be installed in slot 1. A 7753 module can be used in slot 2, but measurement accuracy might be adversely affected because cards are always calibrated in slot 1.

NOTE A displayed channel number on the Model 2790 is made up of the slot (1 or 2) and module channel. Examples:

102 = Slot 1, channel 2
218 = Slot 2, channel 18

Key-press sequences — Test procedures for front panel operation are presented as key-press sequences. For example, the following sequence closes channel 1 for a 7751/7752/7753 installed in slot 1:

Press CLOSE > select MULTI > select 101 > press EXIT

What the sequence means is:

Press CLOSE Press the CLOSE key.
select MULTI Use the edit keys (up or down key) to display the MULTI menu option and press ENTER.
select 101 Use the edit keys (up, down, left, or right arrow keys) to display channel 101 and press ENTER.
press EXIT Press the EXIT key to exit the menu.

Closed channels for test circuits

Test circuits show which channel switches need to be closed to make the test connections. Keep in mind that these, and only these channels must be closed for the test. All other channels in the system must be open. As a rule, ALWAYS open all channels at the beginning and end of a test.

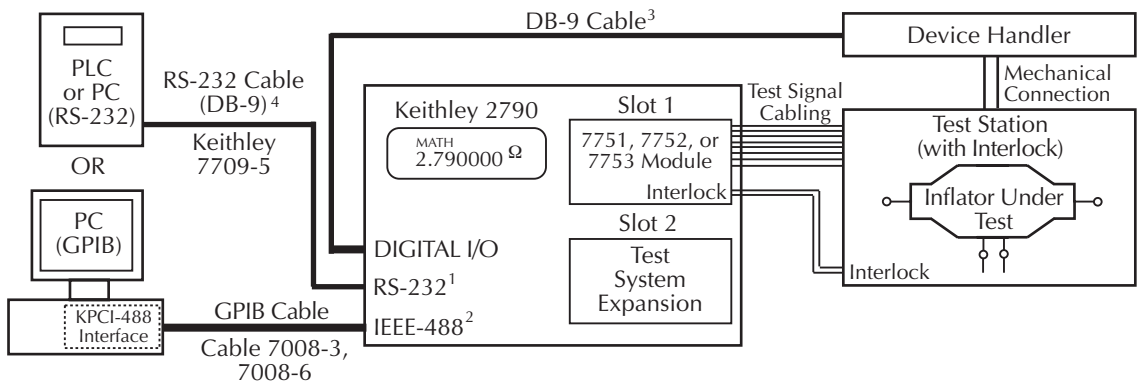
NOTE To use the DMM of the Model 2790 to measure a DUT connected to a switching module, the front panel INPUTS switch must be in the REAR (in) position.

Test system

Figure 5-1 shows a typical test system and connections using a programmable logic controller (PLC) or a PC. Connections for the test signals (and interlock) are covered in “Test signal connections.”

NOTE Only one Model 7753 can be installed in a Model 2790, and it should be installed in slot 1. A 7753 module can be used in slot 2, but measurement accuracy might be adversely affected because cards are always calibrated in slot 1.

Figure 5-1
System connections



1. When using a PLC, select and configure the RS-232 interface of the 2790.
2. If using a PC, select the GPIB interface and set the address of the 2790.
3. Use a cable terminated with a female DB-9 connector to mate to the DIGITAL I/O connector of the 2790.
4. Cable must be wired as a straight-through cable (not null modem cable).

RS-232 interface (PLC or PC)

A PLC uses the RS-232 interface for communications with the Model 2790. A PC can also use the RS-232. Available 2790 settings for the RS-232 interface:

- Baud rate: 19.2K, 9600, 4800, 2400, 1200, 600, or 300
- Flow control: XonXoff or NONE
- Tx terminator: CR, LFCR, LF, or CRLF

The RS-232 menu of the 2790 is accessed by pressing and releasing SHIFT and then pressing RS-232. Once in the menu, use the following key-press sequence to select and configure the RS-232:

Select **RS-232: ON** > select **BAUD** rate > select **FLOW** control > select **Tx TERMinator**

GPIB (PC only)

The GPIB (which is faster than RS-232) can be used if an IEEE-488 Interface card (e.g., KPCI-488) is installed in the computer.

The GPIB menu of the Model 2790 is accessed by pressing and releasing SHIFT and then pressing GPIB. Once in the menu, use the following key-press sequence:

Select **GPIB: ON** > select **ADDRESS** (address 16 is set at factory)

Test signal connections

There are four main test connection drawings (Figures 5-2, 5-3, 5-4, and 5-5), but you only need to use the one that applies to your test system. Select the drawing that best suits your needs and disregard the other three.

NOTE All the test circuits and procedures in this section assume that the inflator is connected to the 7751/7752/7753 module as shown in [Figure 5-2](#) through [Figure 5-5](#).

Single stage inflator test connections:

- [Figure 5-2](#) — Use this connection scheme if using a Keithley 7752 module. It can also be used for the 7751 or 7753 module if not performing the HIPOT test.
- [Figure 5-3](#) — Use this connection scheme if using a Keithley 7751 or 7753 module. It includes the connections for the HIPOT test.

Figure 5-2

Test connections – shunt bar and bridgewire testing – single stage inflator

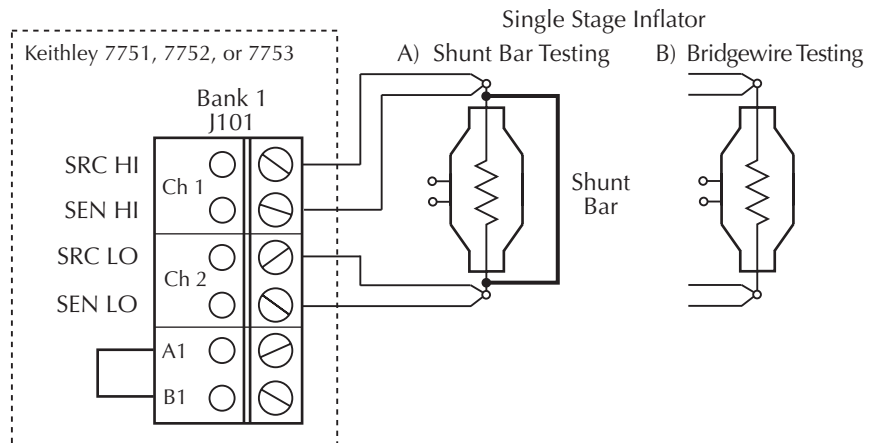
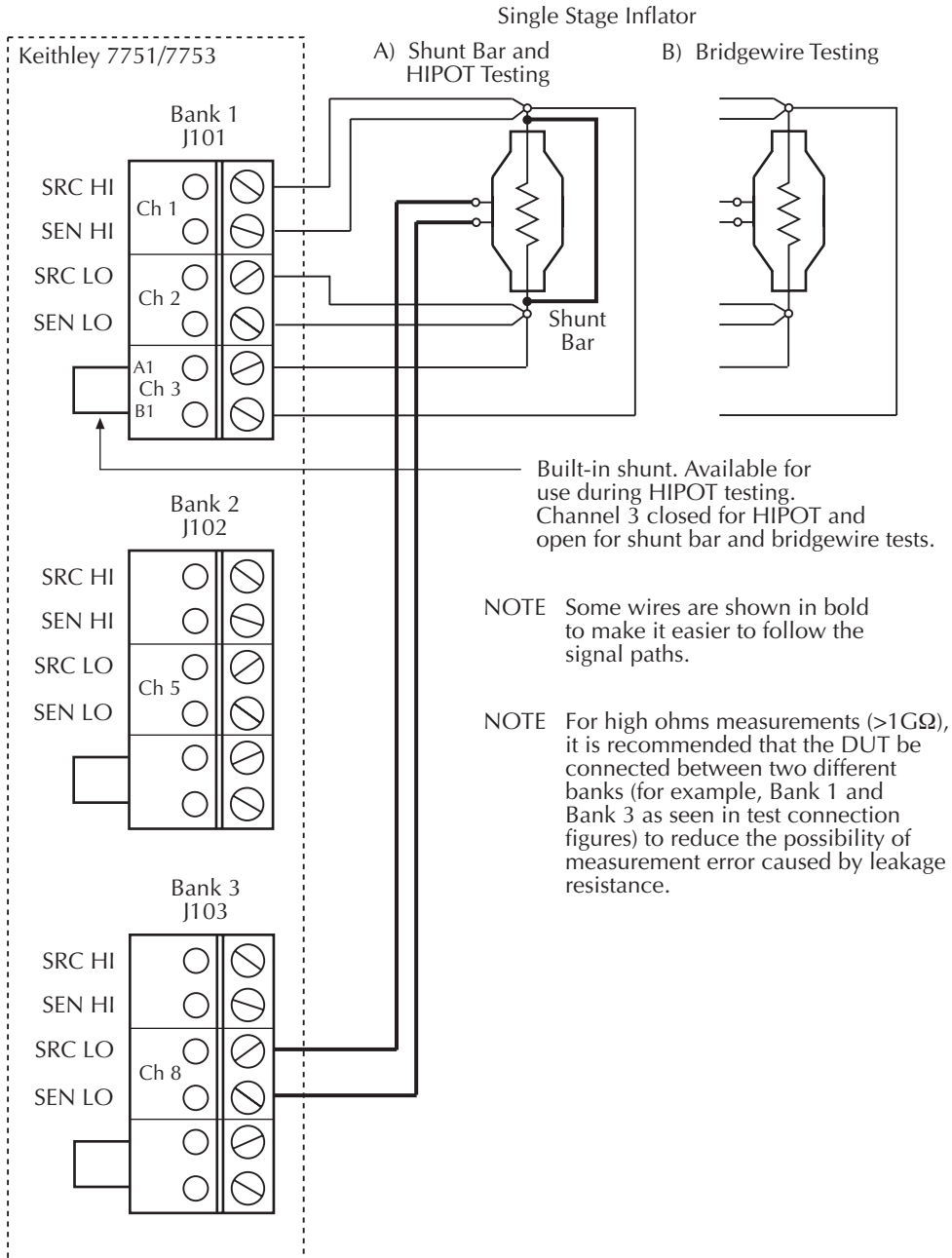


Figure 5-3
Test connections – shunt bar, HIPOT, and bridgewire testing – single stage inflator



Dual stage inflator test connections:

- **Figure 5-4** — Use this connection scheme if using a Keithley 7752 module. It can also be used for the 7751 or 7753 module if not performing the HIPOT test.
- **Figure 5-5** — Use this connection scheme if using a Keithley 7751 or 7753 module. It includes the connections for the HIPOT test.

Figure 5-4

Test connections – shunt bar and bridgewire bar testing – dual stage inflator

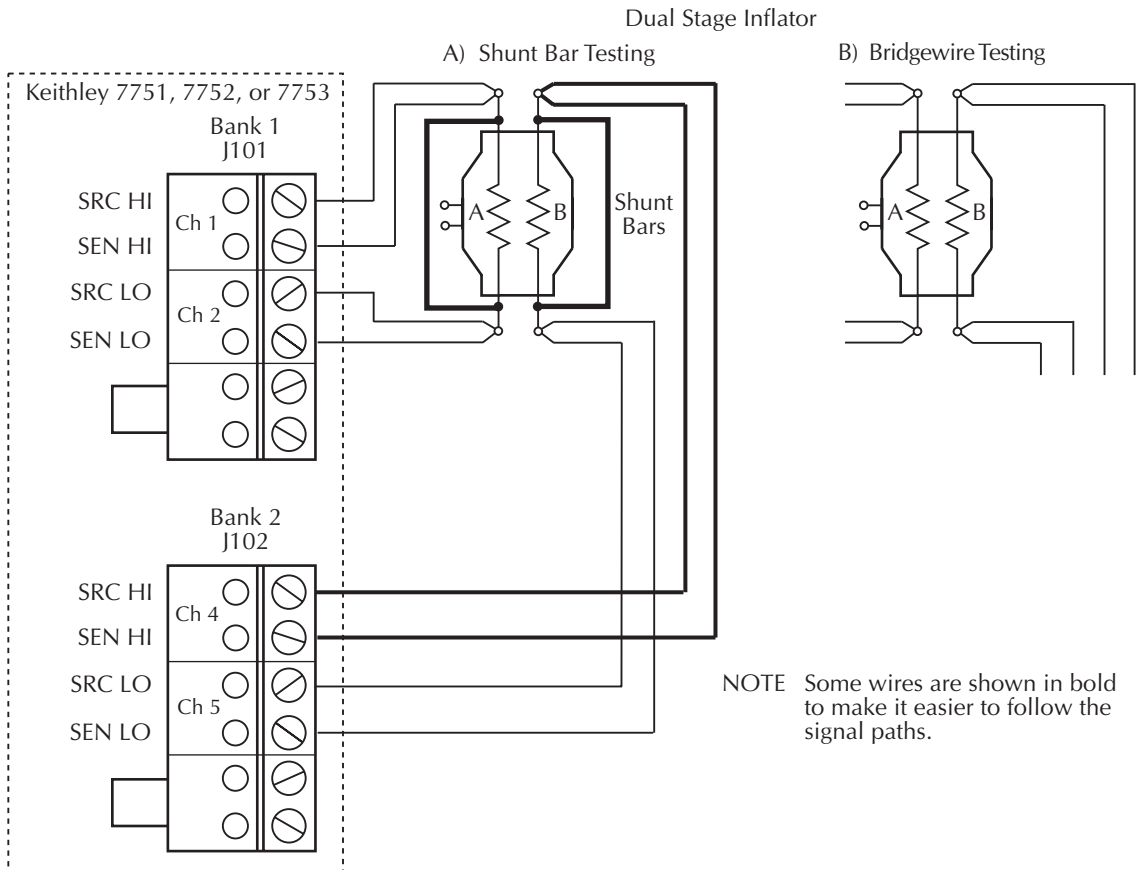
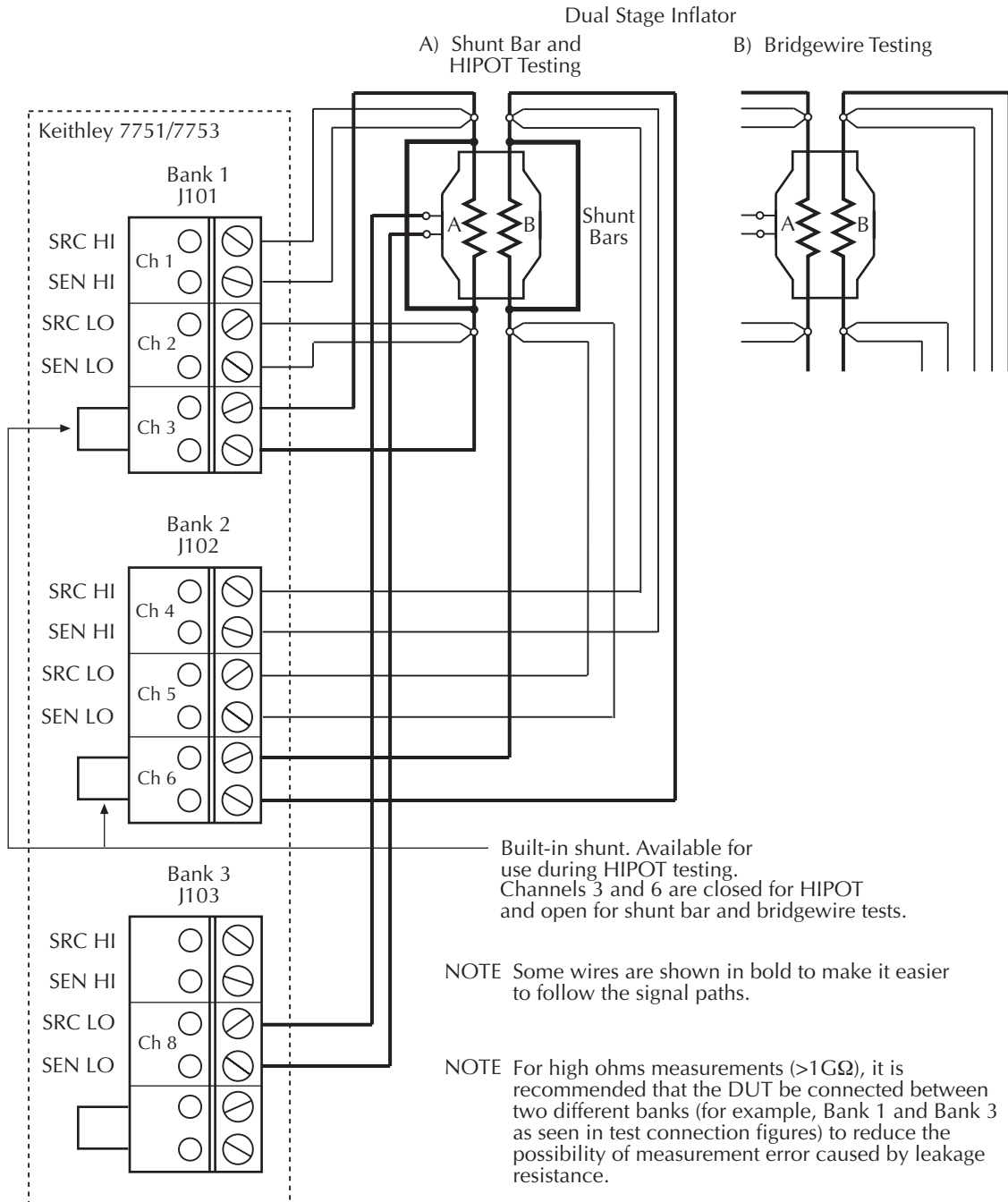


Figure 5-5

Test connections – shunt bar, HIPOT, and bridgewire testing – dual stage inflator

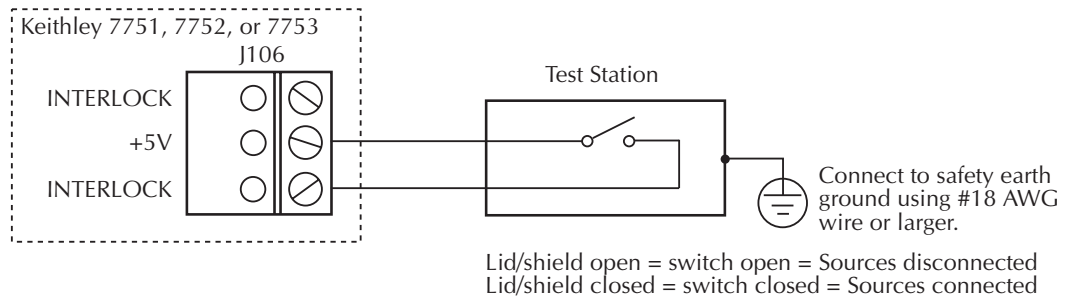


Interlock connections:

Figure 5-6 — When using a test fixture or safety shield that has an interlock switch, connect interlock as shown in Figure 5-6.

Figure 5-6

Interlock connections



WARNING *DO NOT permanently short out the interlock. Interlock is an essential safeguard to prevent personal injury due to electric shock and/or accidental ignition of an inflator.*

It is a good safe practice to use an interlock test station that always disables the sources and provides protection from inflator ignition.

Interlock

NOTE *An enabled interlock allows the I-source and V-source (7751/7753) to be connected to the rest of the switch matrix. An open (disabled) interlock does not disable the sources. The sources are always on and available at the J107 terminals of the module. Interlock has no effect on the source outputs at J107.*

The selected source can also be accessed at J105 (Source Hi and Source Lo) when interlock is enabled. With interlock open, the sources are disconnected.

The interlock of the 7751/7752/7753 module must be enabled in order to connect the I-source or V-source (7751/7753) to the rest of the switch matrix. With interlock disabled, you will not be able to close switches that connect the selected source to the DUT and DMM.

The typical test station has a built-in interlock switch, which is to be connected to INTERLOCK of the 7751/7752/7753. When the test station lid or safety shield is open, the switch will open to disconnect the sources of the 7751/7752/7753.

Figure 5-6 shows how to connect the interlock of the 7751, 7752, or 7753 to the test station.

NOTE As shown in *Figure 5-6*, only connect a switch to J106. Do not connect any external sources to it. The internal +5V source for interlock is referenced to chassis earth ground. If the +5V terminal of J106 comes into contact with earth ground, a fuse on the module will open. After the fault is cleared, the fuse will reset automatically.

With interlock open, the following channels will open and cannot be closed:

- Channel 21 — With this channel open, the selected source is isolated from the rest of the module.
- Channels 18 and 19 — With these channels open, the backplane of the Model 2790 is isolated from the switching module.

Open interlock errors

Details on open interlock errors are provided in [Section 2](#) (see “Open interlock errors”). The following explains the more common errors associated with open interlock:

Front panel messages:

- INTRLCK OPEN is displayed briefly if you attempt to close channel 18, 19, or 21 with interlock open.
- With the INPUTS switch in the REAR position (in), readings will overflow (OFLO) when the interlock is open. The IL1 or IL2 message will also be displayed to identify which slot is in violation. (With both slots in violation, IL1 message takes precedence.)

Remote programming errors:

- When an open interlock is first detected, error +860 (slot 1 interlock violation) or +861 (slot 2 interlock violation) occurs.
- With interlock open, error -224 (parameter error) occurs if you attempt to close channel 18, 19, or 21. It also occurs if you use ROUT:MULT:OPEN to open channel 20 while interlock is open.

Shunt bar test

The resistance of the shunt bar is typically 10 to 100mΩ. It is possible for the contact surfaces of a shunt bar to oxidize, even in normal operating conditions. The presence of any such oxides affects the resistance of the shunt bar.

It may be desirable to test the shunt under dry circuit conditions to prevent the breakdown of any oxide layers, which could give a false indication of the shunt resistance. Dry circuit conditions require that the voltage applied to the DUT be limited to 20mV or less. Closing channel 24 of the 7751/7752/7753 module enables the 20mV dry circuit clamp.

When using the dry circuit, test current is automatically limited to slightly more than 1mA, regardless of the programmed level. Therefore, it is recommended that the I-source output be set to 1mA or less to ensure that a known current is being used for the resistance measurement.

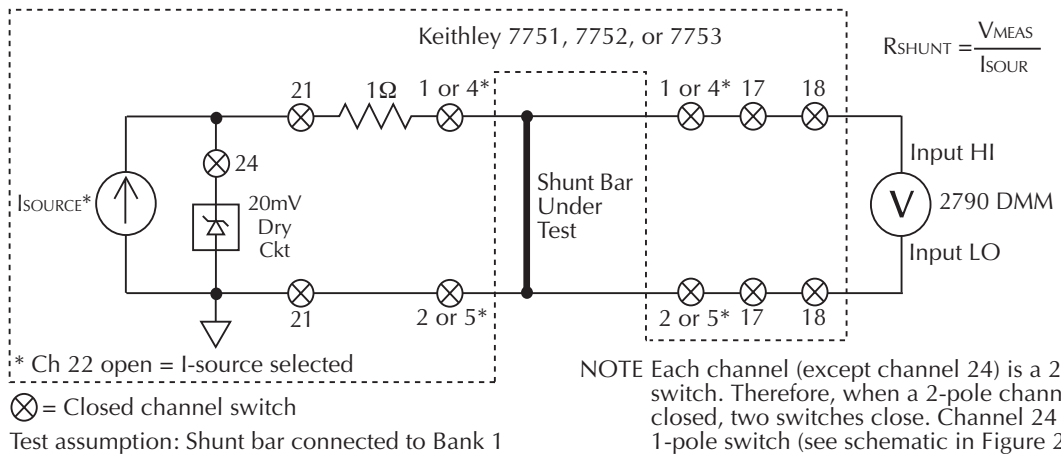
NOTE The SxIohms math functions use the programmed I-source values for their calculations. If the I-source output is not set to 1mA or less while dry circuit is enabled (channel 24 closed), these math functions will give incorrect resistance readings.

NOTE Typically, the shunt bar test is usually the first step in the testing process for an inflator. The typical test station uses a spring-loaded mechanism that automatically installs or removes the shunt bar.

Test circuit

The circuit for the shunt bar test is shown in Figure 5-7. Note that the 20mV dry circuit clamp is used for this test.

Figure 5-7
Test circuit – shunt bar



NOTE Each channel (except channel 24) is a 2-pole switch. Therefore, when a 2-pole channel is closed, two switches close. Channel 24 is a 1-pole switch (see schematic in Figure 2-1).

* Channels 4 and 5 used for dual inflator where each bridgewire has its own shunt bar. See Figure 5-8.

Test procedure

Perform the steps in [Table 5-1](#) to test the shunt bar on a single inflator. The test current for this measurement cannot exceed 1mA due to the dry circuit hardware limit. See [Table 5-2](#) for an example of a test sequence for dual inflator.

I-source readback

The 7751, 7752, and 7753 modules have source readback capabilities. I-source readback allows you to verify the test current used for the shunt bar test. Details on I-source readback are provided in the last topic in this section.

Table 5-1

Test procedure – shunt bar

Test Step	Command Sequence	Front Panel Operation
1) Reset 2790 and open all channels.	*RST	Press SHIFT > press SETUP > select RESTORE: FACT.
2) Set I-source to 1mA.	SOUR:CURR 0.001, (@127)	Press SHIFT > press CARD > select CONFIG > select SLOT1: 7751, 7752, or 7753 > set I-C27 to 01.00 mA > press ENTER > press EXIT or ENTER.
3) Select and enable the low ohms calculation.	CALC1:FORM S1I CALC1:STAT ON	Press SHIFT > press MATH > select S1IOHMS.
4) Close channels to test bridgewire.	ROUT:MULT:CLOS (@101, 102, 117, 118, 124, 121)	Press CLOSE > select MULTI > select 101 > select 102 > select 117 > select 118 > select 124 > select 121 > press EXIT.
5) Verify channels that are closed (optional).	ROUT:MULT:CLOS?	Press SHIFT > press CARD > select VIEW > select SLOT1: 7751, 7752, or 7753. Press EXIT when finished.
6) Perform measurement.	READ?	Take reading from display.
7) Open all channels.	ROUT:OPEN:ALL	Press OPEN > select ALL.

Test step notes:

1. Resetting the 2790 opens all channels, selects the DCV function (auto range), and selects the I-source of the 7751/7752/7753 module. For remote programming, *RST places the 2790 in the one-shot trigger mode. For front panel operation, FACT defaults places the 2790 in the continuous trigger mode.
2. This step sets the I-source to output 1mA. Do not use a higher test current for this dry circuit test. For front panel operation and a 7751/7753 module, the V-source output setting will be displayed after setting the I-source output.
3. This step selects the low resistance calculation ($R = V_{MEAS} / I_{SOUR}$). Selecting S1IOHMS sets DMM to DCV, 1V range.
4. This step closes the channels to make the test connections for the shunt bar test. It assumes shunt bar is connected to Bank 1 of a 7751, 7752, or 7753. Channel 124 is closed before channel 121 so that the clamp is in place before connecting source to signal backplane. Channels are closed in order listed.
5. This step is optional. Use it to verify that the correct channels are closed for the test.
6. For remote programming, READ? triggers and requests a single reading.
7. Always open all channels at the beginning and end of a test.

Bridgewire tests

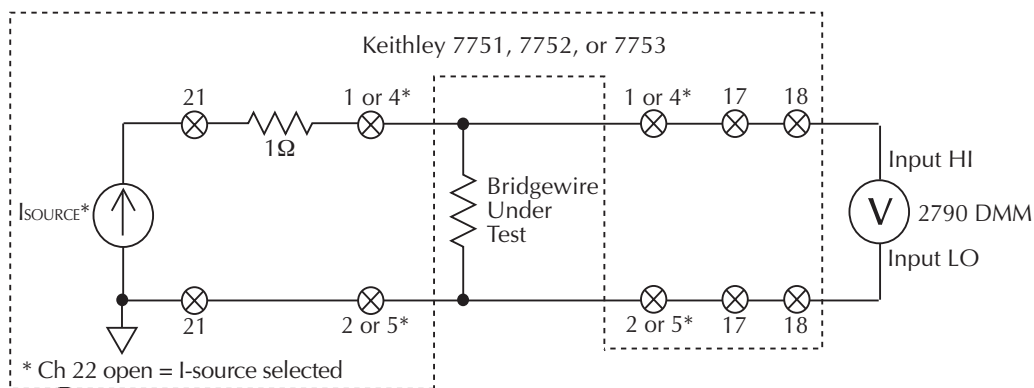
NOTE The interlock of the 7751/7752/7753 must be enabled to use the I-source.
Figure 5-6 shows how interlock is enabled.

Test circuit

The circuit for an inflator bridgewire test is shown in Figure 5-8.

Figure 5-8

Test circuit – bridgewire tests



⊗ = Closed channel switch

* Test assumptions:

- To test bridgewire connected to Bank 1, close input channels 1 and 2.
- To test bridgewire connected to Bank 2, close input channels 4 and 5.

NOTE Each channel is a 2-pole switch. Therefore, when a channel is closed, two switches close (see schematic in Figure 2-1).

Test procedure

Single stage inflator — Perform Test Steps 1 through 7 in [Table 5-2](#).

Dual stage inflator — Perform Test Steps 1 through 11 in [Table 5-2](#).

WARNING To prevent accidental ignition of the inflator, ALWAYS open all channels in the test system at the beginning and end of each test.

Table 5-2

Test procedure – bridgewire

Test Step	Command Sequence	Front Panel Operation
1) Reset 2790 and open all channels.	*RST	Press SHIFT > press SETUP > select RESTORE: FACT.
2) Set I-source to 50mA.	SOUR:CURR 0.05, (@127)	Press SHIFT > press CARD > select CONFIG > select SLOT1: 7751, 7752, or 7753 > set I-C27 to 50.00 mA > press ENTER > press EXIT or ENTER.
3) Select and enable the low ohms calculation.	CALC1:FORM S1I CALC1:STAT ON	Press SHIFT > press MATH > select S1IOHMS.
4) Close channels to test bridgewire.	ROUT:MULT:CLOS (@101, 102, 117, 118, 121)	Press CLOSE > select MULTI > select 101 > select 102 > select 117 > select 118 > select 121 > press EXIT.
5) Verify channels that are closed (optional).	ROUT:MULT:CLOS?	Press SHIFT > press CARD > select VIEW > select SLOT1: 7751, 7752, or 7753. Press EXIT when finished.
6) Perform measurement.	READ?	Take reading from display.
7) Open all channels.	ROUT:OPEN:ALL	Press OPEN > select ALL.
The following steps are used to test the second bridgewire of a dual stage inflator:		
8) Close channels to test 2nd bridgewire.	ROUT:MULT:CLOS (@104, 105, 117, 118, 121)	Press CLOSE > select MULTI > select 104 > select 105 > select 117 > select 118 > select 121 > press EXIT.
9) Verify channels that are closed (optional).	ROUT:MULT:CLOS?	Press SHIFT > press CARD > select VIEW > select SLOT1: 7751, 7752, or 7753. Press EXIT when finished.

Table 5-2 (cont.)

Test procedure – bridgewire

Test Step	Command Sequence	Front Panel Operation
10) Perform measurement.	READ?	Take reading from display.
11) Open all channels.	ROUT:OPEN:ALL	Press OPEN > select ALL.

Test step notes:

1. Resetting the 2790 opens all channels, selects the DCV function (auto range), and selects the I-source of the 7751/7752/7753 module. For remote programming, *RST places the 2790 in the one-shot trigger mode. For front panel operation, FACT defaults places the 2790 in the continuous trigger mode.
2. This step sets the I-source to output 50mA, which is a typical test current used for this test. For front panel operation and a 7751/7753 module, the V-source output setting will be displayed after setting the I-source output.
3. This step selects the low resistance calculation ($R = VMEAS / ISOUR$). Selecting S1IOHMS sets DMM to DCV, 1V range.
4. This step closes the channels to make the test connections for the bridgewire test. It assumes a bridgewire is connected to Bank 1 of a 7751, 7752, or 7753.
5. This step is optional. Use it to verify that the correct channels are closed for the test.
6. For remote programming, READ? triggers and requests a single reading.
7. Always open all channels at the beginning and end of a test.
8. This step closes the channels to make the test connections for the second bridgewire. It assumes the bridgewire is connected to Bank 2 of a 7751, 7752, or 7753.
9. This step is optional. Use it to verify that the correct channels are closed for the test.
10. For remote programming, READ? triggers and requests a single reading.
11. Always open all channels at the beginning and end of a test.

I-source readback

The 7751, 7752, and 7753 modules have source readback capabilities. I-source readback allows you to verify the test current used in the bridgewire test. Details on I-source readback are provided in the last topic in this section.

Insulation resistance (HIPOT) tests (7751/7753 only)

WARNING The Models 7751 and 7753 are provided with outputs that are potentially hazardous if not connected properly. It is the responsibility of the customer to operate instruments in a safe manner. Be sure to read and follow all installation and operating instructions before attempting to use the 7751/7753 HIPOT function.

There are three basic tests for insulation resistance. Two preliminary verification tests and the HIPOT test.

- Contact checks — These checks use the ohmmeter of the Model 2790 to verify that the V-source test circuit is properly connected to the inflator housing and the bridgewire.
- V-source readback — This test uses the voltmeter of the Model 2790 to measure the actual output of the V-source. This test should be done before every HIPOT test to ensure that the programmed voltage is being used.
- Cable discharge — Summarizes cable discharge which is used to dissipate energy stored in the test cables and the module by the V-source.
- HIPOT test — This test measures the insulation resistance of the inflator.

Single stage inflator connections to the 7751/7753 module are shown in [Figure 5-3](#), while dual stage inflator connections are shown in [Figure 5-5](#). These connections accommodate all three tests for insulation resistance.

NOTE The interlock of the 7751/7753 must be enabled in order to use the V-source. [Figure 5-6](#) shows how interlock is enabled.

Contact checks

NOTE *Low-resistance, 2-wire ohms measurement accuracy can be reduced by the resistance of the protective fuses on the 7751/7752/7753 modules, which are in series with the DMM current source output. See “Fuse resistance considerations,” page 6-2 for more information.*

Test circuits

The test circuits to verify contact are shown in [Figure 5-9](#) (single stage inflator) and [Figure 5-10](#) (dual stage inflator). Contact is checked by performing a continuity check through the V-source test leads and the connection points.

Single stage inflator — As shown in [Figure 5-9](#), there are three contact connection points for the V-source test circuit. Contact checks are performed as follows:

- Bank 1 HI contact — Close channels 1, 14, and 18 to check the connection at the HI terminal of the bridgewire.
- Bank 2 housing contact — Close channels 8, 15, and 18 to check the connection at the housing of the inflator.

Dual stage inflator — As shown in [Figure 5-10](#), there are four contact connection points for the V-source test circuits. Contact checks are performed as follows:

- Bank 1 HI contact — Close channels 1, 14, and 18 to check the connection at the HI terminal of bridgewire A.
- Bank 2 housing contact — Close channels 8, 15, and 18 to check the connection at the housing of the inflator.
- Bank 3 HI contact — Close channels 4, 14, and 18 to check the connection at the HI terminal of bridgewire B.

Figure 5-9

Test circuits – contact check – single stage inflator

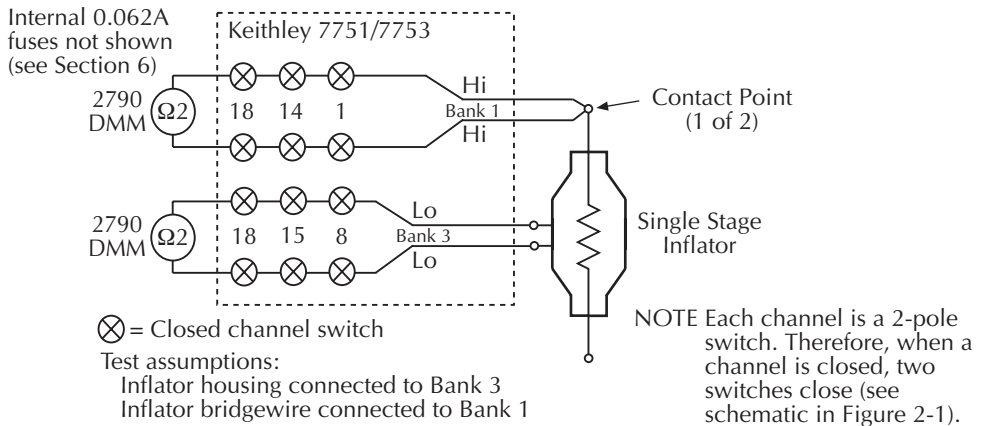
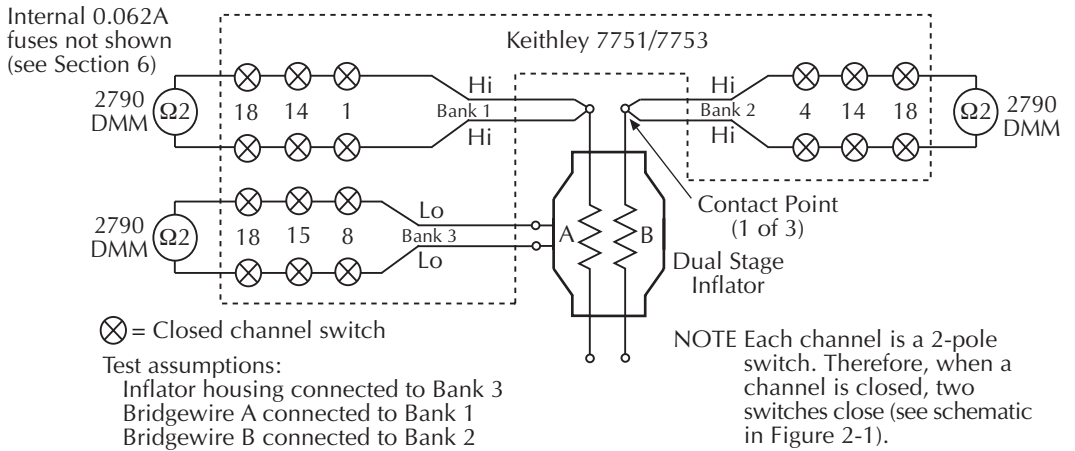


Figure 5-10

Test circuits – contact check – dual stage inflator



Test procedures

Single stage inflator — Perform the Test Steps in [Table 5-3](#).

Dual stage inflator — Perform the Test Steps in [Table 5-4](#).

WARNING To prevent accidental detonation of the inflator, ALWAYS open all channels in the test system at the beginning and end of each test.

Table 5-3

Test procedure – contact checks for single stage inflator

Test Step	Command Sequence	Front Panel Operation
1) Reset 2790 and open all channels.	*RST	Press SHIFT > press SETUP > select RESTORE: FACT.
2) Select $\Omega 2$.	SENS:FUNC 'RES'	Press $\Omega 2$.
3) Close channels to test HI contact.	ROUT:MULT:CLOS (@101,114,118)	Press CLOSE > select MULTI > select 101 > select 114 > select 118 > press EXIT.
4) Verify channels that are closed (optional).	ROUT:MULT:CLOS?	Press SHIFT > press CARD > select VIEW > select SLOT1: 7751 or 7753. Press EXIT when finished.
5) Perform measurement.	READ?	Take reading from display.
6) Open all channels.	ROUT:OPEN:ALL	Press OPEN > select ALL.
7) Close channels to test housing contact.	ROUT:MULT:CLOS (@108,115,118)	Press CLOSE > select MULTI > select 108 > select 115 > select 118 > press EXIT.
8) Verify channels that are closed (optional).	ROUT:MULT:CLOS?	Press SHIFT > press CARD > select VIEW > select SLOT1: 7751, 7752, or 7753. Press EXIT when finished.
9) Perform measurement.	READ?	Take reading from display.
10) Open all channels.	ROUT:OPEN:ALL	Press OPEN > select ALL.

Test step notes:

1. Resetting the 2790 opens all channels and selects the DCV function (auto range). For remote programming, *RST places the 2790 in the one-shot trigger mode. For front panel operation, FACT defaults places the 2790 in the continuous trigger mode.
2. This step selects the $\Omega 2$ measurement function of the Model 2790.
3. This step closes the channels to make the connections for the HI contact test.
4. This step is optional. Use it to verify that the correct channels are closed for the test.
5. For remote programming, READ? triggers and requests a single reading.
6. Always open all channels at the beginning and end of a test.
7. This step closes the channels to make the connections for the housing contact test.
8. This step is optional. Use it to verify that the correct channels are closed for the test.
9. For remote programming, READ? triggers and requests a single reading.
10. Always open all channels at the beginning and end of a test.

Table 5-4

Test procedure – contact checks for dual stage inflator

Test Step	Command Sequence	Front Panel Operation
1) Reset 2790 and open all channels.	*RST	Press SHIFT > press SETUP > select RESTORE: FACT.
2) Select $\Omega 2$.	SENS:FUNC 'RES'	Press $\Omega 2$.
3) Close channels to test HI contact for bridgewire A.	ROUT:MULT:CLOS (@101,114,118)	Press CLOSE > select MULTI > select 101 > select 114 > select 118 > press EXIT.
4) Verify channels that are closed (optional).	ROUT:MULT:CLOS?	Press SHIFT > press CARD > select VIEW > select SLOT1: 7751 or 7753. Press EXIT when finished.
5) Perform measurement.	READ?	Take reading from display.
6) Open all channels.	ROUT:OPEN:ALL	Press OPEN > select ALL.
7) Close channels to test HI contact for bridgewire B.	ROUT:MULT:CLOS (@104,114,118)	Press CLOSE > select MULTI > select 104 > select 114 > select 118 > press EXIT.
8) Verify channels that are closed (optional).	ROUT:MULT:CLOS?	Press SHIFT > press CARD > select VIEW > select SLOT1: 7751 or 7753. Press EXIT when finished.
9) Perform measurement.	READ?	Take reading from display.
10) Open all channels.	ROUT:OPEN:ALL	Press OPEN > select ALL.
11) Close channels to test housing contact.	ROUT:MULT:CLOS (@108,115,118)	Press CLOSE > select MULTI > select 108 > select 115 > select 118 > press EXIT.
12) Verify channels that are closed (optional).	ROUT:MULT:CLOS?	Press SHIFT > press CARD > select VIEW > select SLOT1: 7751, 7752, or 7753. Press EXIT when finished.
13) Perform measurement.	READ?	Take reading from display. Reading should be 2Ω or less.
14) Open all channels.	ROUT:OPEN:ALL	Press OPEN > select ALL.

Test step notes:

1. Resetting the 2790 opens all channels and selects the DCV function (auto range). For remote programming, *RST places the 2790 in the one-shot trigger mode. For front panel operation, FACT defaults places the 2790 in the continuous trigger mode.
2. This step selects the $\Omega 2$ measurement function of the Model 2790.
3. This step closes the channels to make the connections for the HI contact test (bridgewire A).
4. This step is optional. Use it to verify that the correct channels are closed for the test.
5. For remote programming, READ? triggers and requests a single reading.
6. Always open all channels at the beginning and end of a test.
7. This step closes the channels to make the connections for the HI contact test (bridgewire B).
8. This step is optional. Use it to verify that the correct channels are closed for the test.
9. For remote programming, READ? triggers and requests a single reading.
10. Always open all channels at the beginning and end of a test.
11. This step closes the channels to make the connections for the housing contact test.
12. This step is optional. Use it to verify that the correct channels are closed for the test.
13. For remote programming, READ? triggers and requests a single reading.
14. Always open all channels at the beginning and end of a test.

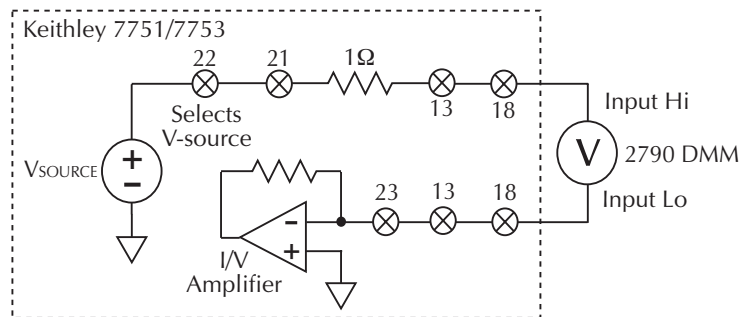
V-source readback

Test circuit

The V-source readback circuit is shown in Figure 5-11. Closing channels 13, 18, 21, 22, and 23 routes the voltage to the DMM of the Model 2790. The DMM needs to be on the 1000V range to measure the maximum output of the 7751/7753 (500V).

Figure 5-11

V-source readback circuit



⊗ = Closed channel switch

NOTE Each channel (except channel 23) is a 2-pole switch. Therefore, when a 2-pole channel is closed, two switches close. Channel 23 is a 1-pole switch (see schematic in Figure 2-1).

Open switches not used in the test circuit are not shown.

Test procedure

Perform the steps in [Table 5-5](#) to verify the open-circuit output of the V-source.

Table 5-5

Test procedure – V-source readback

Test Step	Command Sequence	Front Panel Operation
1) Reset 2790 and open all channels.	*RST	Press SHIFT > press SETUP > select RESTORE: FACT.
2) Close channels to connect V-source.	ROUT:MULT:CLOS (@113,118,121,122,123)	Press CLOSE > select MULTI > select 113 > select 118 > select 121 > select 122 > select 123 > press EXIT.
3) Verify channels that are closed (optional).	ROUT:MULT:CLOS?	Press SHIFT > press CARD > select VIEW > select SLOT1: 7751 or 7753. Press EXIT when finished.
4) Perform measurement.	READ?	Take reading from display.
5) Open all channels.	ROUT:OPEN:ALL	Press OPEN > select ALL.

Test step notes:

1. Resetting the 2790 opens all channels and selects the DCV function (auto range). For remote programming, *RST places the 2790 in the one-shot trigger mode. For front panel operation, FACT defaults places the 2790 in the continuous trigger mode.
2. This step closes the channels to connect the V-source output to the DMM of the Model 2790.
3. This step is optional. Use it to verify that the correct channels are closed for the test.
4. For remote programming, READ? triggers and requests a single reading.
5. Always open all channels at the beginning and end of a test.

Cable discharge

After using the V-source of the 7751/7753 module, a charge may be stored in the test cables and module signal paths. The resulting voltage could ignite the inflator if it is connected across a bridgewire. Therefore, a cable discharge circuit is used to safely dissipate the charge.

In brief, cable discharge is automatically implemented when the OPEN:ALL operation is performed. As long as the test cables are connected to the module, and the input channels (i.e., channels 1 and 2) are closed, all stored energy in the circuit will dissipate safely.

NOTE Details on the cable discharge circuit are provided in [Section 2](#).

NOTE The test procedure for HIPOT uses the OPEN:ALL operation to perform cable discharge (see steps 7 and 11 in [Table 5-6](#)).

NOTE For high ohms measurements ($>1G\Omega$), it is recommended that the DUT be connected between two different banks (for example, Bank 1 and Bank 3 as seen in test connection figures) to reduce the possibility of measurement errors caused by leakage resistance.

HIPOT test

This test is used to measure the leakage resistance between an initiator (bridgewire) and the housing.

Single stage inflator connections to the 7751/7753 module is shown in [Figure 5-3](#), while dual stage inflator connections are shown in [Figure 5-5](#).

NOTE The interlock of the 7751/7753 must be enabled in order to use the V-source. [Figure 5-6](#) shows how interlock is enabled.

Test circuit

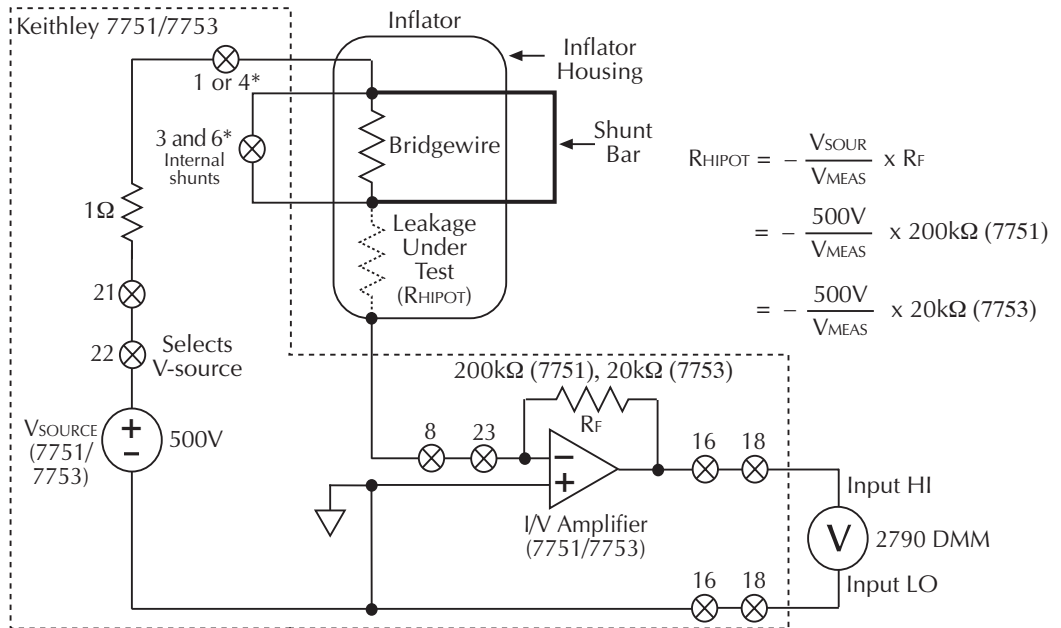
The circuit for the HIPOT test is shown in [Figure 5-12](#).

Internal shunts — The HIPOT test is usually performed with the shunt bar installed. This shorts the bridgewire to prevent accidental ignition of the inflator. However, if the short bar is not installed or should it become defective, the protection is gone. Therefore, the 7751, 7752, and 7753 provide built-in shunts. They can be used in lieu of, or with the shunt bars to provide additional safety. As shown in [Figure 5-12](#), closing channel 3 or 6 connects the internal shunt across the bridgewire.

Single stage inflator — Closing input channel 1 connects the first bridgewire.

Dual stage inflator — Closing input channel 4 connects the second bridgewire.

Figure 5-12
Test circuit – HIPOT



⊗ = Closed channel switch

* Test assumptions:

To test a single inflator connected to Bank 1, close channels 1 and 3. Closing channel 3 connects an internal, built-in shunt across the bridgewire.

To test a dual inflator connected to Banks 1 and 2, close channels 3, 4, and 6. Closing channels 3 and 6 connects internal, built-in shunts across the two bridgewires.

NOTE Each channel (except channel 23) is a 2-pole switch. Therefore, when a 2-pole channel is closed, two switches close. Channel 23 is a 1-pole switch (see schematic in Figure 2-1).

Open switches not used in the test circuit are not shown.

Test procedure – HIPOT

WARNING The following test procedure involves hazardous voltages. It is the responsibility of the customer to operate instruments in a safe manner. Be sure to read and follow the instructions for connecting and wiring the tester in [Section 4](#) before operating the equipment.

NOTE To ensure the reliability of the HIPOT test, it should be performed after verifying contact (Contact checks) and the output of the V-source (V-source readback).

Single stage inflator — Perform Test Steps 1 through 7 in [Table 5-6](#).

Dual stage inflator — Perform Test Steps 1 through 11 in [Table 5-6](#).

Table 5-6

Test procedure – HIPOT

Test Step	Command Sequence	Front Panel Operation
1) Reset 2790 and open all channels.	*RST	Press SHIFT > press SETUP > select RESTORE: FACT.
2) Set V-source to 500V.	SOUR:VOLT 500, (@128) (Include a 250msec program delay to allow source to settle).	Press SHIFT > press CARD > select CONFIG > select SLOT1: 7751 or 7753 > display V-C28 > set to 500.0 V.
3) Select and enable the high ohms calculation.	CALC1:FORM S1V CALC1:STAT ON	Press SHIFT > press MATH > select S1VOHMS.
4) Close channels to perform HIPOT test.	ROUT:MULT:CLOS (@101, 103, 108, 116, 118, 121, 122, 123)	Press CLOSE > select MULTI > select 101 > select 103 > select 108 > select 116 > select 118 > select 121 > select 122 > select 123 > press EXIT.
5) Verify channels that are closed (optional).	ROUT:MULT:CLOS?	Press SHIFT > press CARD > select VIEW > select SLOT2: 7751 or 7753. Press EXIT when finished.
6) Perform measurement.	READ?	Take reading from display.
7) Perform cable discharge and open all channels.	ROUT:OPEN:ALL	Press OPEN > select ALL.
<i>The following steps are used to test insulation resistance for the second bridgewire of a dual stage inflator:</i>		
8) Close channels to perform HIPOT test for second bridgewire.	ROUT:MULT:CLOS (@104, 106, 108, 116, 118, 121, 122, 223)	Press CLOSE > select MULTI > select 104 > select 106 > select 108 > select 116 > select 118 > select 121 > select 122 > select 123 > press EXIT.

Table 5-6 (cont.)

Test procedure – HIPOT

Test Step	Command Sequence	Front Panel Operation
9) Verify channels that are closed (optional).	ROUT:MULT:CLOS?	Press SHIFT > press CARD > select VIEW > select SLOT1: 7751 or 7753. Press EXIT when finished.
10) Perform measurement.	READ?	Take reading from display.
11) Perform cable discharge and open all channels.	ROUT:OPEN:ALL	Press OPEN > select ALL.

Test step notes:

1. Resetting the 2790 opens all channels, selects the DCV function (auto range), and selects the I-source of the 7751/7753 module. For remote programming, *RST places the 2790 in the one-shot trigger mode. For front panel operation, FACT defaults places the 2790 in the continuous trigger mode.
2. This step sets the V-source to output 500V, which is a typical voltage for this test. Note that this menu is also used to set the I-source output. Simply skip over the I-source setting.
3. This step selects the high resistance calculation ($R = V_{SOUR} / I_{MEAS}$). Selecting S1VOHMS sets the DMM to DCV, 10V range.
4. This step closes the channels to make the test connections for the HIPOT test. It assumes the single stage inflator is connected as shown in [Figure 5-3](#).
5. This step is optional. Use it to verify that the correct channels are closed for the test.
6. For remote programming, READ? triggers and requests a single reading.
7. Performs cable discharge for input channels 1 and 2, and opens all channels.
8. This step closes the channels to make the test connections for the second HIPOT test. It assumes the dual stage inflator is connected as shown in [Figure 5-5](#).
9. This step is optional. Use it to verify that the correct channels are closed for the test.
10. For remote programming, READ? triggers and requests a single reading.
11. Performs cable discharge for input channels 4 and 5, and opens all channels.

I-source readback

This readback circuit measures the actual current that is flowing in the test circuit through the DUT (bridgewire or shunt bar). It is used to verify that the programmed current level of the I-source is being used in the tests.

NOTE I-source readback is only accurate to 1%. It is only intended as a verification and not a high accuracy measurement.

The I-source readback circuits are shown in [Figure 5-13](#). [Figure 5-13A](#) shows how to measure the current for the bridgewire test, while [Figure 5-13B](#) shows how to measure the current for the shunt bar test.

In both circuits, the Model 2790 DMM measures the voltage across the 1Ω resistor (V_{MEAS}). Readback current (I_{RB}) is then calculated using Ohms Law ($I_{RB} = V_{MEAS} / 1\Omega$).

Make sure to open all channels before closing the appropriate channels for I-source readback. When finished, make sure to again open all channels.

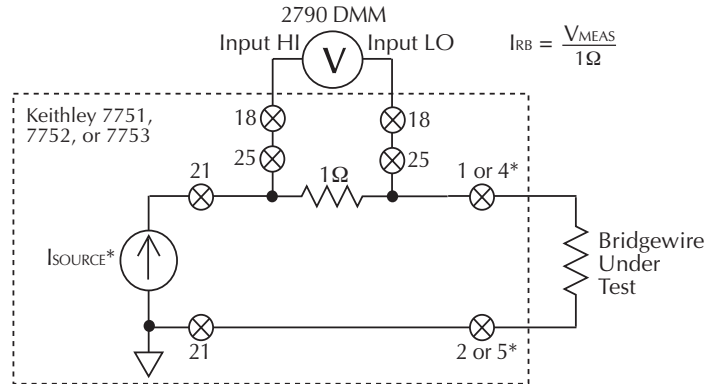
The mX+b calculation can be used to read the I-source current in amps by setting “m” to 1.0 and “b” to 0.0:

Front panel operation: Press SHIFT > press MATH > select mX+B > set M to +1.0 > set B to 0.0 > select UNITS: A

Remote programming: `CALC:FORM MXB`
`CALC:KMAT:MMF 1.0`
`CALC:KMAT:MBF 0.0`
`CALC:KMAT:MUN 'A'`
`CALC:STAT ON`

Figure 5-13
I-source readback circuit

A) Test circuit for current source readback (bridgewire)



⊗ = Closed channel switch

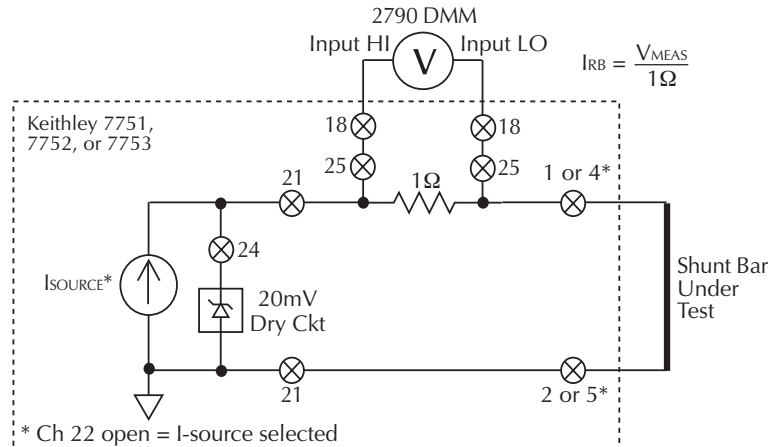
* Ch 22 open = I-source selected

Test assumptions:

- To test inflator connected to Bank 1, close channels 1 and 2.
- To test inflator connected to Bank 2, close channels 4 and 5.

NOTE Each channel, except channel 24, is a 2-pole switch. Therefore, when a 2-pole channel is closed, two switches close. Channel 24 is a 1-pole switch (see schematic in Figure 2-1).
Open switches not used in the test circuit are not shown.

B) Test circuit for current source readback (shunt bar)



* Ch 22 open = I-source selected

Test assumption: Shunt bar connected to Bank 1

⊗ = Closed channel switch

* Channels 4 and 5 closed for applications with two shunt bars

Memory patterns test

As discussed in [Section 2](#), Model 2790 units equipped with firmware revision A04 and higher have the capability of using memory patterns to simplify repetitive test procedures. The discussion below shows how to use memory patterns to make contact checks on a dual-stage inflator.

NOTE See [Section 2 of the Model 2790 Reference Manual](#) for a more detailed memory patterns example.

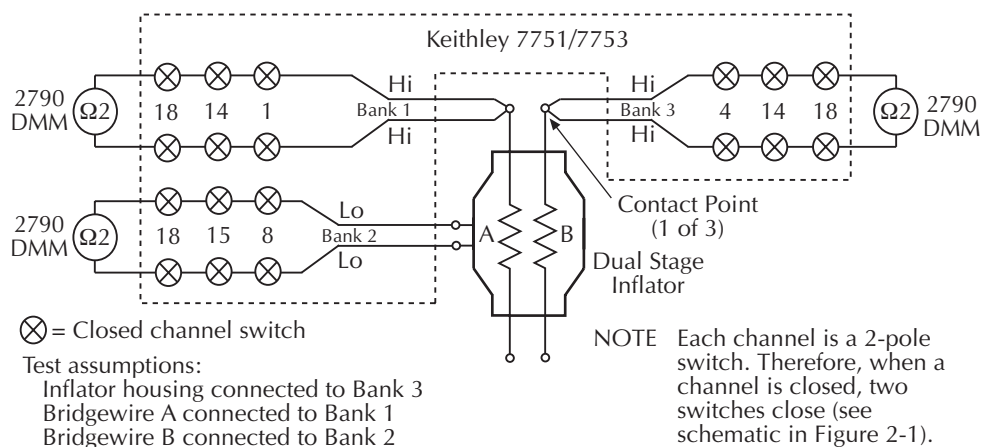
Test circuit

As shown in [Figure 5-14](#), there are four contact connection points for the V-source test circuits. Contact checks are performed as follows:

- Bank 1 HI contact — Close channels 1, 14, and 18 to check the connection at the HI terminal of bridgewire A.
- Bank 2 housing contact — Close channels 8, 15, and 18 to check the connection at the housing of the inflator.
- Bank 3 HI contact — Close channels 4, 14, and 18 to check the connection at the HI terminal of bridgewire B.

Figure 5-14

Test circuits – memory patterns – dual stage inflator contact test



Test procedure

The basic test procedure for using memory patterns to perform contact tests on a dual-state inflator using scanning is shown in [Table 5-7](#). The same test procedure using individual memory pattern location recall is shown in [Table 5-8](#).

This procedure sets up three memory locations for the necessary relay closures. Each memory location is set up as follows:

- Delay: 0s
- Function: 2-wire ohms
- Range: 100
- Integration period: 1 PLC

After setting up memory locations ([Table 5-7](#)), the scan is enabled, triggered, and readings are stored in the buffer for recall once the scan is complete. For the memory pattern location recall shown in [Table 5-8](#), memory locations are first set up, and each location is recalled in succession.

Table 5-7

Command sequence for memory patterns test example using scanning

Command Sequence	Description
*RST	Restore GPIB defaults.
ROUT:MEM:CLE:ALL	Clear all memory pattern locations.
<i>Set up memory location 1:</i>	
ROUT:MEM:CHAN 1, (@101,114,118)	Set channels 1, 14, and 18 for memory location 1.
ROUT:MEM:DEL 1,0	Set delay to 0.
ROUT:MEM:READ:STAT 1, ON	Enable reading.
SENS:FUNC 'RES', (@M1)	Select 2-wire ohms.
SENS:RES:RANG 100, (@M1)	Select 100Ω range.
SENS:RES:NPLC 1, (@M1)	Select 1 PLC.
<i>Set up memory location 2:</i>	
ROUT:MEM:CHAN 2, (@104,114,118)	Set channels 4, 14, and 18 for memory location 2.
ROUT:MEM:DEL 2,0	Set delay to 0.
ROUT:MEM:READ:STAT 2, ON	Enable reading.
SENS:FUNC 'RES', (@M2)	Select 2-wire ohms.
SENS:RES:RANG 100, (@M2)	Select 100Ω range.
SENS:RES:NPLC 1, (@M2)	Select 1 PLC.

Table 5-7 (cont.)

Command sequence for memory patterns test example using scanning

Command Sequence	Description
<i>Set up memory location 3:</i>	
ROUT:MEM:CHAN 3, (@108,115,118)	Set channels 8, 15, and 18 for memory location 3.
ROUT:MEM:DEL 3,0	Set delay to 0.
SENS:FUNC 'RES', (@M3)	Select 2-wire ohms.
SENS:RES:RANG 100, (@M3)	Select 100Ω range.
SENS:RES:NPLC 1, (@M3)	Select 1 PLC.
ROUT:MEM:READ:STAT 3,ON	Enable reading.
<i>Set up to scan, trigger scan, store readings:</i>	
ROUT:SCAN (@M1,M2,M3)	Set up scan for three memory locations.
TRIG:SOUR IMM	Immediate trigger source.
TRIG:COUN 1	Trigger count = 1.
SAMP:COUN 3	Sample count = 3.
TRAC:CLE	Clear buffer.
TRAC:POIN 3	Store three readings in buffer.
TRAC:FEED:CONT NEXT	Enable buffer.
ROUT:SCAN:LSEL INT	Enable scan.
INIT	Trigger scan.
<i>Wait for scan to complete before continuing:</i>	
ROUT:SCAN:LSEL NONE	Disable scan.
TRAC:FEED:CONT NEVER	Disable buffer.
ROUT:OPEN:ALL	Open all relays.
FORM:ELEM READ	Send readings only from buffer.
TRAC:DATA?	Request all buffer readings.

Table 5-8

Command sequence for memory patterns test example using individual memory pattern recall

Command Sequence	Description
*RST	Restore GPIB defaults.
ROUT:MEM:CLE:ALL	Clear all memory pattern locations.
<i>Set up memory location 1:</i>	
ROUT:MEM:CHAN 1, (@101,114,118)	Set channels 1, 14, and 18 for memory location 1.
ROUT:MEM:DEL 1,0	Set delay to 0.
ROUT:MEM:READ:STAT 1, ON	Enable reading.
SENS:FUNC 'RES', (@M1)	Select 2-wire ohms.
SENS:RES:RANG 100, (@M1)	Select 100Ω range.
SENS:RES:NPLC 1, (@M1)	Select 1 PLC.
<i>Set up memory location 2:</i>	
ROUT:MEM:CHAN 2, (@104,114,118)	Set channels 4, 14, and 18 for memory location 2.
ROUT:MEM:DEL 2,0	Set delay to 0.
ROUT:MEM:READ:STAT 2, ON	Enable reading.
SENS:FUNC 'RES', (@M2)	Select 2-wire ohms.
SENS:RES:RANG 100, (@M2)	Select 100Ω range.
SENS:RES:NPLC 1, (@M2)	Select 1 PLC.
<i>Set up memory location 3:</i>	
ROUT:MEM:CHAN 3, (@108,115,118)	Set channels 8, 15, and 18 for memory location 3.
ROUT:MEM:DEL 3,0	Set delay to 0.
ROUT:MEM:READ:STAT 3, ON	Enable reading.
SENS:FUNC 'RES', (@M3)	Select 2-wire ohms.
SENS:RES:RANG 100, (@M3)	Select 100Ω range.
SENS:RES:NPLC 1, (@M3)	Select 1 PLC.
FORM:ELEM READ	Send readings only from buffer.
<i>Recall memory locations, trigger/request readings:</i>	
ROUT:MEM:REC 1	Recall memory pattern 1.
READ?	Trigger and request reading.
ROUT:MEM:REC 2	Recall memory pattern 2.
READ?	Trigger and request reading.
ROUT:MEM:REC 3	Recall memory pattern 3.
READ?	Trigger and request reading.

6

Model 2790 DMM

Ohms Functions

- **Introduction** — Summarizes the differences between the methods used by the Model 2790 DMM and the 7751/7752/7753 modules to measure resistance.
- **4-wire ohms** — Explains the benefits of using the 4-wire ohms technique to measure low resistance.
- **Offset compensated ohms** — Explains the offset compensated ohms feature which is used to cancel the adverse effects of offset voltages present in the test circuit.
- **Keithley 7702 module** — Shows how to use the ohms functions of the Model 2790 DMM with the 7702 module.
- **Keithley 7751, 7752, and 7753 modules** — Shows how to use the ohms functions of the Model 2790 DMM with the 7751/7752/7753 module.

Introduction

As a general rule for testing inflators, the programmable I-source of the 7751/7752/7753 modules should be used to measure low resistance (bridgwires and shunt bars). The programmable V-source of the 7751/7753 module should be used to measure insulation resistance. For other resistance measurements (wiring harnesses, fuse blocks, switches/relays, etc.), an ohms function ($\Omega 2$ or $\Omega 4$) of the Model 2790 can be used.

Low ohms measurements

The ohms functions of the Model 2790 provide better accuracy than the I-source method used by the 7751/7752/7753 module. However, the test current used by the Model 2790 is fixed. For the 100 Ω and 1k Ω ranges, the test current is fixed at 1mA.

Low-ohms accuracy comparison:

- When using the current source of the 7751, 7752, or 7753 module to perform 4-wire, low ohms measurements, accuracy is 0.09% (@50mA).
- For the Model 2790, when using the $\Omega 4$ function (4-wire ohms), 100 Ω range, and offset compensation, basic resistance measurement accuracy is 0.01% (1 year spec).

Fuse resistance considerations

Two fuses (F3 and F4) are in series with the output of the on-card current source to insure that the test current cannot exceed 62mA. Fuses F1 and F2 are in series with the backplane connection to the meter INPUT HI. For DMM resistance measurements, these fuses are in series with the mainframe current source; similar to F3 and F4, these fuses limit the mainframe current output to a maximum of 62mA. Because fuses F1 and F2 are in series with the DMM output, they appear as “lead resistance” in a 2-wire measurement. As a result, the measured value of a short circuit connected to channels 1, 2, 4, 5, 7, 8, 10, or 11 and measured with the DMM in 2-wire ohms will basically equal the resistance of these fuses plus any additional trace and lead resistance.

The nominal cold resistance of a single fuse is about 5.5 Ω . Therefore, when you measure a short through the 7751/7752/7753 modules using the DMM 2-wire ohms function (for example, contact checks), you will actually read two times the fuse resistance plus any trace and other lead resistance. The resistance of these fuses is fairly temperature sensitive. Typically, a short measured right at the channel terminals reads between 12 Ω (cold) to approximately 15 Ω (hot). Although not usually a problem, you can correct for this offset using the REL function of the DMM, subtract the offset from the readings in your test program, or you can simply adjust pass/fail limits.

NOTE *Fuse resistance does not affect 4-wire measurements, which sense around the lead resistance.*

High ohms measurements

The 7751 and 7753 include a programmable V-source (50 to 500V), so the constant voltage method can be used to measure high resistance (such as insulation resistance). The Model 2790 mainframe does not have a voltage source.

If not using a 7751 or 7753 module in your test system, you can use the $\Omega 2$ function (100M Ω range) of the Model 2790 to measure insulation resistance up to 120M Ω .

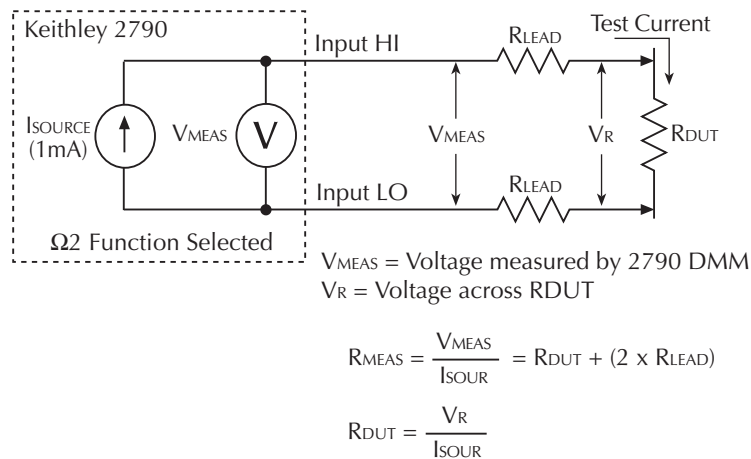
4-wire ohms

4-wire ohms eliminates the effects of test lead resistance when measuring a low ohms DUT. **Figure 6-1** shows how 2-wire ohms can be adversely affected when measuring a low ohms DUT.

If the test lead resistance (R_{LEAD}) is relatively large in comparison to the resistance of the DUT (R_{DUT}), the measured voltage (V_{MEAS}) will include the voltage drops across the two test leads. Therefore, the measured voltage (which is used to calculate resistance) will not be the same as the actual voltage (V_R) across R_{DUT} .

Figure 6-1

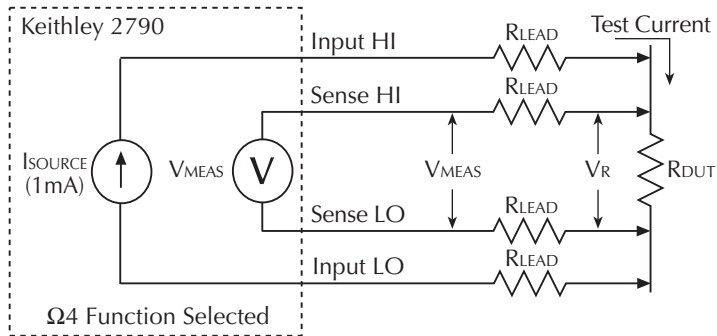
Using $\Omega 2$ function to measure resistance



The 4-wire (Kelvin) connection method shown in Figure 6-2 should be used for low resistance measurements. With this configuration, the test current is forced through R_{DUT} through one set of test leads, while the voltage is measured through a second set of test leads (called sense leads).

Due to the high impedance of the DMM of the Model 2790, negligible current will flow through the sense leads. Since the voltage across the sense leads will be negligible, the voltage measured by the DMM (V_{MEAS}) is essentially the same as the voltage across the DUT (V_R).

Figure 6-2
Using $\Omega 4$ function to measure resistance



V_{MEAS} = Voltage measured by 2790 DMM

V_R = Voltage across R_{DUT}

Because sense current is negligible, $V_{MEAS} = V_R$

Therefore:

$$R_{MEAS} = \frac{V_{MEAS}}{I_{SOUR}} = \frac{V_R}{I_{SOUR}} = R_{DUT}$$

Offset compensated ohms

The presence of thermal EMFs (V_{EMF}) can adversely affect low-resistance measurement accuracy. To overcome these unwanted offset voltages, you can use offset-compensated ohms (OCOMP). Offset compensated ohms performs two measurements using two different test currents. The two readings are then averaged to yield a single resistance reading.

NOTE Details on offset compensated ohms are provided in Section 3 of the Model 2790 Reference Manual.

Offset-compensated ohms measurements can be performed on the 100 Ω , 1k Ω , and 10k Ω ranges for the $\Omega 4$ function.

Front panel operation

Perform the following steps to enable offset compensated ohms:

1. Press $\Omega 4$ to select the 4-wire resistance function (4W annunciator on).
2. Use the RANGE up and down keys to select the 100 Ω , 1k Ω , or 10k Ω range.
3. Press and release SHIFT and then OCOMP to enable offset compensated ohms (OCOMP annunciator on).

Remote programming

The commands to control offset compensated ohms are listed in Table 6-1.

Table 6-1

Commands to set offset compensated ohms

Commands	Description	Default
[SENSe[1]]		
:FUNction 'FRESistance' [, <clist>]	Select 4-wire ohms function ($\Omega 4$).	
:FUNction? [<clist>]	Query function.	
:FRESistance:RANGe <n> [, <clist>]	Select range; 0 to 11e3*.	100e6**
:FRESistance:RANGe? [<clist>]	Query $\Omega 4$ range.	
:FRESistance:OCOMPensated [, <clist>]	Enable or disable offset compensated ohms; ON or OFF.	OFF**
:FRESistance:OCOMPensated? [<clist>]	Query state of OCOMP.	

* Suggested parameters:

To select 100 Ω range; let <n> = 100

To select 1k Ω range; let <n> = 1e3

To select 10k Ω range; let <n> = 10e3

** SYSTEM:PRESet and *RST disables offset compensated ohms and selects the 100M Ω range for the $\Omega 4$ function.

Keithley 7702 module

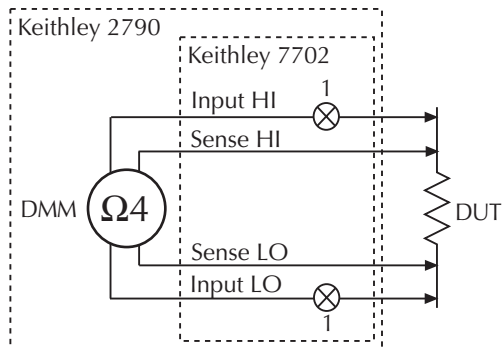
The 40 two-wire (or 20 four-wire) input channels of the 7702 module make it ideal to test multiple DUT. With system channel operation, a single channel closure connects a DUT to the Model 2790 DMM for measurement. Testing multiple DUT can be further automated using the scanning feature of the Model 2790. Once configured, the testing process can be started with a single press of a button (or when commanded for remote programming).

NOTE Details on scanning 7702 channels are provided in Section 7 of the Model 2790 Reference Manual.

Figure 6-3 shows the simplified test circuit for using the $\Omega 4$ function of the Model 2790 with the 7702 module to measure low ohm DUT. The DUT is connected to channels 1 and 21 of the 7702. When channel 1 is closed using system channel operation, the DUT connects to the DMM of the Model 2790.

Figure 6-3

Using Model 2790 4-wire ohms with 7702 module (low ohms measurements)



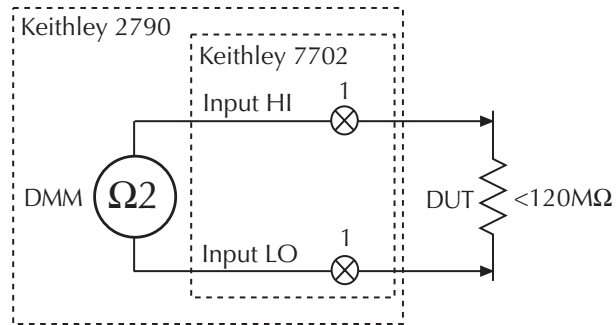
⊗ = Channel closed by user (system channel operation).

The channels that also close when Ch 1 is closed are not shown. These include the paired input channel (Ch 21) the 4-pole relay (Ch 43) and backplane channels (Chs 44 and 45).

Figure 6-4 shows the simplified test circuit for using the $\Omega 2$ function of the Model 2790 with the 7702 module to measure high ohm DUT (i.e., insulation resistance) up to $120\text{M}\Omega$. The DUT is connected to channel 1 of the 7702. When channel 1 is closed using system channel operation, the DUT connects to the DMM of the Model 2790.

Figure 6-4

Using Model 2790 2-wire ohms with 7702 module (high ohms measurements)



⊗ = Channel closed by user (system channel operation).
Not shown is the backplane channel (Ch 45) that also closes when channel 1 is closed.

Keithley 7751, 7752, and 7753 modules

The 7751, 7752, and 7753 modules can also be used with the $\Omega 2$ and $\Omega 4$ functions of the Model 2790. However, since these modules do not support system channel operation, the user must close all appropriate channels using multiple channel operation to make the connection to the DUT. Details on multiple channel operation are provided in [Section 2](#).

[Figure 6-5](#) shows the simplified test circuit for using the $\Omega 4$ function of the Model 2790 with the 7751/7752/7753 module to measure the resistance of a DUT. The DUT is connected to channels 10 and 11 (Bank 4) of the 7751/7752/7753. To connect the DUT to the DMM of the Model 2790, channels 10, 11, 13, 18, and 19 must be closed. Note that the voltage across the DUT is *not* sensed through the fuse resistance (see “[Fuse resistance considerations](#),” [page 6-2](#)), so that measurement accuracy is not affected by fuses.

Figure 6-5

**Using Model 2790 4-wire ohms with 7751/7752/7753 module
(low ohms measurements)**

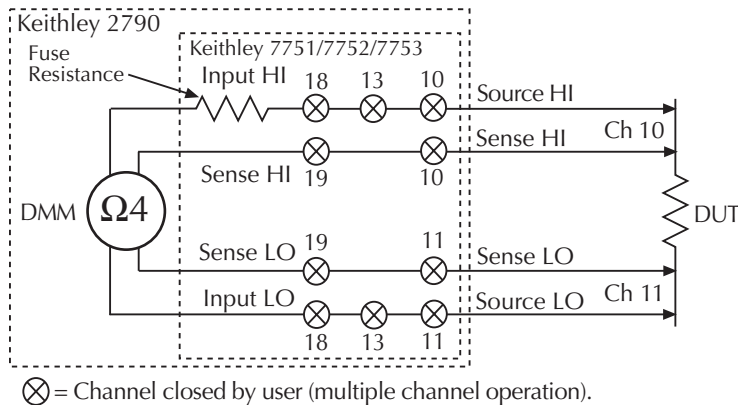
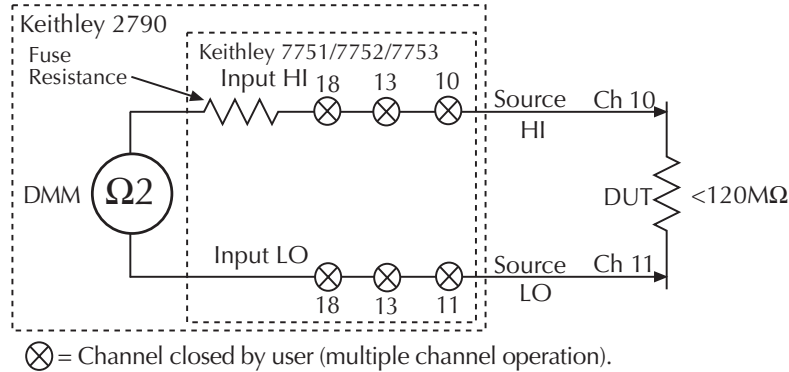


Figure 6-6 shows the simplified test circuit for using the $\Omega 2$ function of the Model 2790 with the 7751/7752/7753 module to measure high ohms DUT (i.e., insulation resistance) up to $120\text{M}\Omega$. The DUT is connected to channels 10 and 11 (Bank 4) of the 7751/7752/7753. To connect the DUT to the DMM of the Model 2790, channels 10, 11, 13, and 18 must be closed. Note that the voltage across the DUT is sensed through the fuse resistance, so that measurement accuracy can be affected by fuses when making low ohms measurements.

NOTE When using the 2-wire ohms function of the Model 2790 to measure a resistance through one of the 775X modules, there will be an offset in the measured value due to the signal path resistance of the 775X module (see “Fuse resistance considerations” on page 6-2). This path resistance is due to safety circuitry (fuses) in the module. The offset can be corrected for by measuring a zero ohm load (short circuit) and then using the REL function (see Section 5 of the Model 2790 Reference Manual) to remove the offset. 4-wire ohms measurements are not affected by the safety circuitry.

Figure 6-6
Using Model 2790 2-wire ohms with 7751/7752/7753 module
(high ohms measurements)



A Specifications

(Models 2790, 7751, 7752, 7753, and 7702)

- **Models 2790/7751/7752/7753 specifications** — Provides the complete instrument specifications for the Model 2790 SourceMeter Switch System, including the specifications for the Models 7751, 7752, and 7753 modules.
- **Ohms specification calculations (7751/7752/7753)** — Provides equations to calculate ohms specifications for source levels not specified in the 7751/7752/7753 module specifications.
- **Model 7702 specifications** — Provides the complete specifications for the Model 7702 module.

2790 SourceMeter® Switch System Specifications

7751/7752/7753 SOURCE/SWITCH MODULE SPECIFICATIONS

2790 Resistance Mode Specifications with Cards^{2,3} (Module function accuracy specifications are for 2 years, 23°C, ±5°C)

Source Current	Maximum Resistance	Typ. Open Ckt. Voltage	Accuracy %Rdg + Ohms	Temperature Coefficient (0-18°C & 28-40°C)
50mA	20Ω	5.5V	0.09% + 40mΩ	(0.002%+3mΩ)/°C
20mA	50Ω	5.5V	0.11% + 40mΩ	(0.003%+3mΩ)/°C
10mA	100Ω	5.5V	0.16% + 40mΩ	(0.004%+3mΩ)/°C

(Dry Circuit Ohms 1mA max with 7751, 7752, or 7753 card)

1mA	10Ω	20mV	1.10% + 40mΩ	(0.026%+3mΩ)/°C
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(7751 Only)

Source Voltage	Resistance Range	Max. Short Ckt. Current	Accuracy %Rdg	Temperature Coefficient (0-18°C & 28-40°C)
500V	10MΩ	<1mA	0.8%	0.03%/°C
500V	100MΩ	<1mA	1.1%	0.05%/°C
500V	1GΩ	<1mA	4.0%	0.12%/°C
50V	1MΩ	<1mA	1.1%	0.04%/°C
50V	10MΩ	<1mA	1.1%	0.06%/°C
50V	100MΩ	<1mA	1.6%	0.13%/°C

(7753 Only)

Source Voltage	Resistance Range	Max. Short Ckt. Current	Accuracy %Rdg	Temperature Coefficient (0-18°C & 28-40°C)
500V	1MΩ	<1mA	0.8%	0.02%/°C
500V	10MΩ	<1mA	0.9%	0.03%/°C
500V	100MΩ	<1mA	1.3%	0.10%/°C
500V	1GΩ	<1mA	6.7%	0.27%/°C
50V	0.1MΩ	<1mA	1.1%	0.03%/°C
50V	1MΩ	<1mA	1.1%	0.04%/°C
50V	10MΩ	<1mA	1.3%	0.11%/°C
50V	100MΩ	<1mA	4.5%	0.30%/°C

Current Source Output

Output Level: Programmable 0 to 50mA (Ch. 27).

Programming Resolution: 10μA.

Output Voltage: 5.5V±10% compliance.

Accuracy: 0.06% + 10μA (2 yr Specification).

Settling Time: 1mS to 0.1% of final value (typ).

Temperature Coefficient: (0-18°C & 28-40°C)
(0.001%+0.25μA)/°C

Dry Circuit Clamp (Ch. 24): 20mV±10%, I_{source} ≤1mA

Voltage Source Output (7751/7753 Only)

Output Level: Programmable 50V to 500V (CH. 28).

Programming Resolution: 100mV.

Output Current: (7751) - 50μA maximum for rated accuracy, <1mA typical into short circuit.
(7753) - 500μA maximum for rated accuracy, <1mA typical into short circuit.

Accuracy: 0.5% + 0.13V (2yr Specification).

Settling Time: Rise Time: 50V to 500V step, 0.1% of final value, 250 ms max.
Fall Time: 500V to 50V step, 0.1% of final value, 1000 ms max.

Temperature Coefficient: (0-18°C & 28-40°C)
(0.001%+0.005V)/°C

Safety Limit: Current limited maximum current of 1mA.

Cable Discharge (Ch. 20): 100kΩ Shunt

Max Capacitance: 1nF

Current Measure Input (7751/7753 Only)

Range: 7751 (0-50μA), 7753 (0-500μA).

Accuracy: (7751) 0.5% (of reading) + 6nA (2yr Specification).
(7753) 0.5% (of reading) + 60nA (2yr Specification).

Temperature Coefficient: (0-18°C & 28-40°C) (0.02%+0.5nA)/°C

Voltage Burden: <1mV.

Switching Capabilities (Bank 1 – Bank 4)

4 Channels: 1 Form A switch.

8 Channels: 4 4-pole or 8 2-pole signals into DMM or I/V converter.

Contact Check: 4-Wire contact check through internal DMM.

Relay Type: Latching electromechanical.

Actuation Time: <3ms.

Contact Life (typ): >10⁶ operations at maximum source level.
>10⁸ operations cold switching.

Contact Resistance: <1 Ohm at end of contact life.

Contact Potential: <±2μV typical per contact pair, ±3μV max.

Connector Type: Pluggable screw terminal, #22 AWG wire size.

Isolation Between any two Terminals¹: >1GΩ, <100pF.

Isolation Between Terminals and Earth¹: >1GΩ, <200pF.

Isolation Between Channel Groups¹: >500GΩ, <100pF.

External Common Mode Voltage: 42V between any terminal and chassis.
(Connect no external sources.)

7751, 7752, or 7753 Module Notes

¹ Isolation for channels 1-12, only one channel closed at a time, or all channels open.

² See User's manual for ohm specifications at sources other than those specified.

³ All specifications valid for 1 NPLC ADC aperture setting.

System Throughput

(Connect, source, measure, calculate)

0.01 NPLC, Filter Off, over GPIB Bus

High Ohms (Source V): 13 Rdgs/Sec¹

Low Ohms (Source I): 9 Rdgs/Sec

1 NPLC, Filter On, Over GPIB Bus

High Ohms (Source V): 11 Rdgs/Sec¹

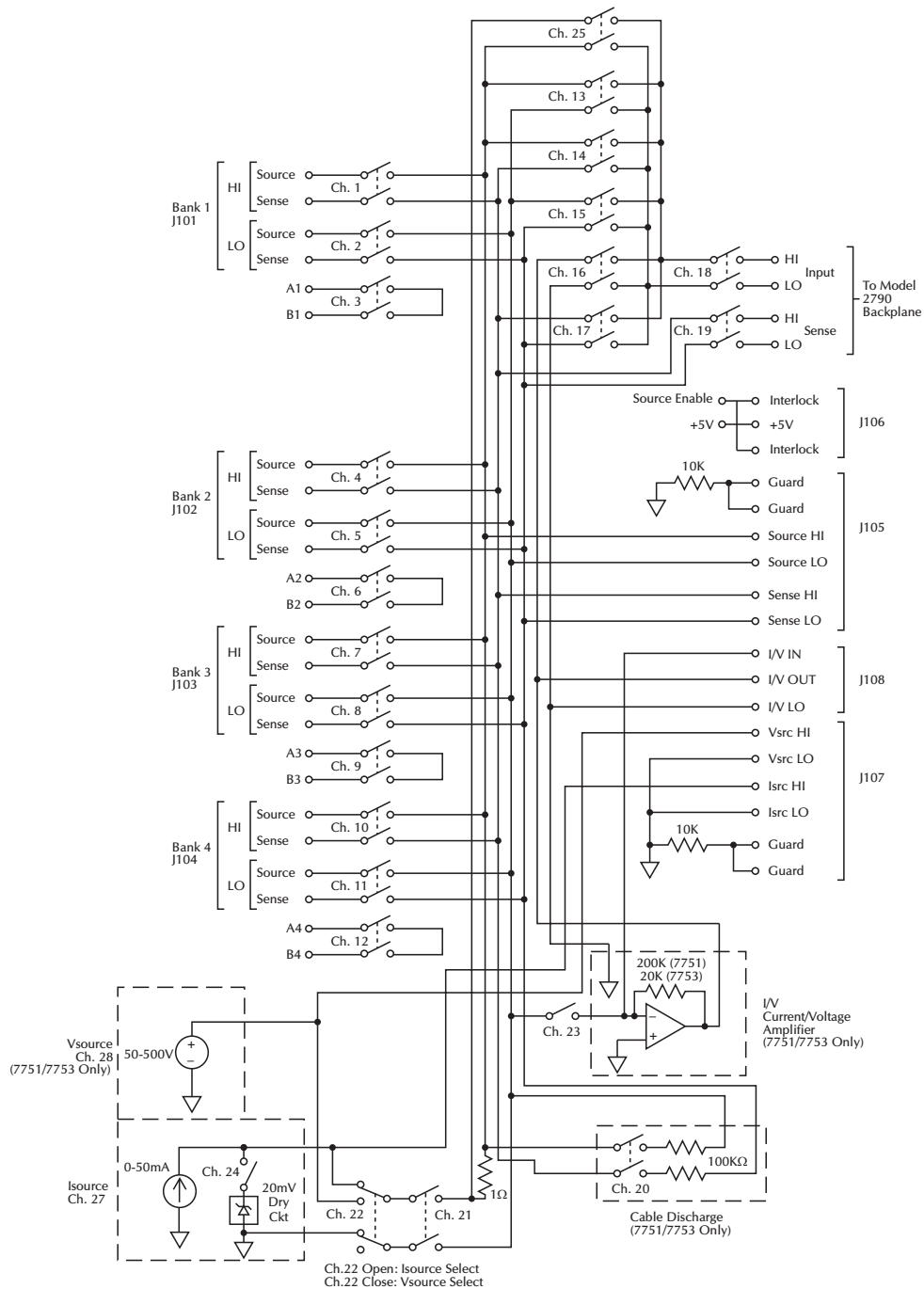
Low Ohms (Source I): 7 Rdgs/Sec

System Throughput Notes

1. Reset upon fixed V_{source} level, no settling time.

2790 SourceMeter® Switch System Specifications

7751/7752/7753 SOURCE/SWITCH MODULE SPECIFICATIONS



2790 SourceMeter® Switch System Specifications

2790 MAINFRAME FUNCTION SPECIFICATION

MAINFRAME FUNCTION ACCURACY SPECIFICATIONS ARE FOR 1 YEAR, 23°C±5°C

DC MEASUREMENT SPECIFICATIONS¹

CONDITIONS: MED (1 PLC)² or 10 PLC
or MED (1 PLC) with Digital Filter of 10

ACCURACY: ±(ppm of reading + ppm of range)
(ppm = parts per million) (e.g., 10ppm = 0.001%)

Function	Range	Resolution	Test Current (±5%) or Burden Voltage	Input Resistance or Open Ckt. Voltage ³	24 Hour ⁴ 23°C ±1°	90 Day 23°C ±5°	1 Year 23°C ±5°	Temperature Coefficient 0°-18°C & 28°-40°C
Voltage	100.0000 mV	0.1 μV		>10 GΩ	15 + 30	25 + 70	30 + 70	(1 + 5)/°C
	1.000000 V	1.0 μV		>10 GΩ	15 + 6	25 + 7	30 + 7	(1 + 1)/°C
	10.00000 V	10 μV		>10 GΩ	10 + 4	20 + 5	30 + 5	(1 + 1)/°C
	100.0000 V	100 μV		10 MΩ ±1%	15 + 6	45 + 9	55 + 9	(5 + 1)/°C
	1000.000 V ⁵	1 mV		10 MΩ ±1%	20 + 6	35 + 9	50 + 9	(5 + 1)/°C
Resistance^{6,8}	100.0000 Ω	100 μΩ	1 mA	6.6 V	20 + 20	80 + 20	100 + 20	(8 + 1)/°C
	1.000000 kΩ	1 mΩ	1 mA	6.6 V	20 + 6	80 + 6	100 + 6	(8 + 1)/°C
	10.00000 kΩ	10 mΩ	100 μA	6.6 V	20 + 6	80 + 6	100 + 6	(8 + 1)/°C
	100.0000 kΩ	100 mΩ	10 μA	12.8 V	20 + 6	80 + 10	100 + 10	(8 + 1)/°C
	1.000000 MΩ	1.0 Ω	10 μA	12.8 V	20 + 6	80 + 10	100 + 10	(8 + 1)/°C
	10.00000 MΩ ⁷	10 Ω	Note 7	7.0 V	150 + 6	200 + 10	400 + 10	(70 + 1)/°C
	100.0000 MΩ ⁷	100 Ω	Note 7	7.0 V	800 + 30	3000 + 30	3000 + 30	(385 + 1)/°C
Continuity (2W)	1.000 kΩ	100 mΩ	1 mA	6.6 V	40 + 100	100 + 100	100 + 100	(8 + 1)/°C
Current	20.00000 mA	10 nA	<0.2 V		60 + 30	300 + 80	500 + 80	(50 + 5)/°C
	100.0000 mA	100 nA	<0.05 V		100 + 300	300 + 800	500 + 800	(50 + 5)/°C
	1.000000 A	1.0 μA	<0.3 V ⁹		200 + 30	500 + 80	800 + 80	(50 + 5)/°C
	3.000000 A	10 μA	<1.0 V ⁹		1000 + 15	1200 + 40	1200 + 40	(50 + 5)/°C
Channel (Ratio)¹⁰	Ratio Accuracy = Accuracy of selected Channel Range + Accuracy of Paired Channel Range							
Channel (Average)¹⁰	Average Accuracy = Accuracy of selected Channel Range + Accuracy of Paired Channel Range							

Temperature

(Displayed in °C, °F, or K. Exclusive of probe errors.)

Range	Resolution	Accuracy 1 Year (23°C ± 5°C)	Temperature Coefficient 0-18°C & 28°-40°C
4-Wire RTD: (100Ω platinum [PT100], D100, F100, PT385, PT3916, or user type. Offset compensation On.)			
-200°C to 630°C	0.01°C	0.06°C	0.003°C/°C
Thermistor: (2.2kΩ, 5kΩ, and 10kΩ)¹⁸			
-80°C to 150°C	0.01°C	0.08°C	0.002°C/°C

DC Speed vs. Noise Rejection

Rate	Filter	Readings/s ¹¹	Digits	RMS Noise 10V Range	NMRR	CMRR ¹³
10	50	0.01 (0.08)	6.5	< 1.2 μV	110 dB ¹²	120 dB
1	Off	15 (12)	6.5	< 4 μV	90 dB ¹²	120 dB
0.1	Off	500 (400)	5.5	< 22 μV	-	80 dB
0.01	Off	2000 (1800)	4.5	< 150 μV	-	80 dB

DC Operating Characteristics¹⁵

60Hz (50Hz) Operation

Function	Digits	Readings/s	PLCs
DCV, DCI, Ohms (<10M), Thermistor	6.5 ^{11, 15}	5 (4)	10
	6.5 ¹⁵	30 (24)	1
	6.5 ^{11, 15}	50 (40)	1
	5.5 ^{11, 15}	100 (80)	0.1
	5.5 ^{15, 16}	250 (200)	0.1
4W Ohms (<10M)	5.5 ¹⁶	480 (400)	0.1
	4.5 ¹⁶	2000 (1800)	0.01
	6.5 ¹⁵	1.4 (1.1)	10
RTD	6.5 ¹⁵	15 (12)	1
	5.5 ^{15, 16}	33 (25)	0.1
	6.5 ¹⁵	0.9 (0.7)	10
Channel (Ratio), Channel (AVG)	6.5 ¹⁵	8 (6.4)	1
	5.5 ^{15, 16}	18 (14.4)	0.1
	6.5 ¹⁵	2.5 (2)	10
Channel (Ratio), Channel (AVG)	6.5 ¹⁵	15 (12)	1
	5.5 ¹⁶	25 (20)	0.1

2790 SourceMeter® Switch System Specifications

MAINFRAME FUNCTION SPECIFICATION

DC System Speeds^{14, 17}

RANGE CHANGES¹⁵: 50/s (42/s).

FUNCTION CHANGES¹⁵: 50/s (42/s).

AUTORANGE TIME¹⁵: < 30ms.

ASCII READINGS TO RS-232 (19.2k BAUD): 55/s.

MAX. INTERNAL TRIGGER RATE: 2000/s.

MAX. EXTERNAL TRIGGER RATE: 375/s.

DC MEASUREMENT CHARACTERISTICS

DC Volts

A-D LINEARITY: 2.0 ppm of reading + 1.0 ppm of range.

INPUT IMPEDANCE:

100mV–10V Ranges: Selectable >10GΩ// with <400pF or 10MΩ ±1%.

100V, 1000V Ranges: 10MΩ ±1%.

INPUT BIAS CURRENT: <100pA at 23°C.

COMMON MODE CURRENT: <500nA p-p at 50Hz or 60Hz.

INPUT PROTECTION: Front, 1000V, Rear, 300V, 7702 card only.

Resistance

MAX 4WΩ LEAD RESISTANCE: 10% of range per lead for 100Ω and 1kΩ ranges; 1kΩ per lead for all other ranges.

OFFSET COMPENSATION: Selectable on 4WΩ, 100Ω, 1kΩ, and 10kΩ ranges.

CONTINUITY THRESHOLD: Adjustable 1 to 1000 Ω.

INPUT PROTECTION: Front, 1000V Source Inputs, 350V Sense Inputs, Rear, 300V, 7702 card only.

DC Current

Shunt Resistors: 100mA–3A, 0.1Ω, 20mA, 5Ω.

Input Protection: 3A, 250V fuse.

DC Notes

¹ 20% overrange except on 1000V and 3A.

² Add the following to “ppm of range” uncertainty; 100mV 15ppm, 1V and 100V 2ppm, 100Ω 30ppm, <1MΩ 2ppm, 10mA and 1A 10ppm, 100mA 40ppm.

³ ±2% (measured with 10MΩ input resistance DMM, >10GΩ DMM on 10MΩ and 100MΩ ranges).

⁴ Relative to calibration accuracy.

⁵ For signal levels >500V, add 0.02ppm/V uncertainty for portion exceeding 500V.

⁶ Specifications are for 4-wire Ω, 100Ω with offset compensation on. With offset compensation on, OPEN CKT. VOLTAGE is 12.8V. For 2-wire Ω add 1Ω additional uncertainty.

⁷ Must have 10% matching of lead resistance in Input HI and LO. Test current +0.7μA||10MΩ

⁸ Add the following to “ppm of reading” uncertainty when using plug in modules:

	10 kΩ	100 kΩ	1 MΩ	10 MΩ	100 MΩ
7702, 7751, 7752				220 ppm	2200 ppm

⁹ Add 1V when used with plug-in modules.

¹⁰ For RATIO, DCV only. For AVERAGE, DCV only. Available with plug-in modules only.

¹¹ Auto zero off.

¹² For LSYNC On, line frequency ±0.1 %. For LSYNC Off, use 60dB for ≥ 1PLC.

¹³ For 1kΩ unbalance in LO lead.

¹⁴ Speeds are for 60Hz (50Hz) operation using factory defaults operating conditions (*RST). Autorange off, Display off, Limits off, Trigger delay = 0.

¹⁵ Speeds include measurements and binary data transfer out the GPIB.

¹⁶ Sample count = 1024, auto zero off.

¹⁷ Auto zero off, NPLC = 0.01.

¹⁸ For lead resistance >0Ω, add the following uncertainty/Ω for measurement temperatures of:

	70°–100°C	100°–150°C
2.2 kΩ (44004)	0.22°C	1.11°C
5.0 kΩ (44007)	0.10°C	0.46°C
10 kΩ (44006)	0.04°C	0.19°C

2790 SourceMeter® Switch System Specifications

MAINFRAME FUNCTION SPECIFICATION

AC MEASUREMENT SPECIFICATIONS¹

Function	Range	Resolution	All Ranges Calibration Cycle	All Ranges Accuracy: ±(% of reading + % of range), 23°C ±5 °C				
				3 Hz-10 Hz ¹³	10 Hz-20 kHz	20 kHz-50 kHz	50 kHz-100 kHz	100 kHz-300 kHz
Voltage ²	100.0000 mV	0.1 μV	90 Days	0.35 + 0.03	0.05 + 0.03	0.11 + 0.05	0.6 + 0.08	4.0 + 0.5
	1.000000 V	1.0 μV	1 Year	0.35 + 0.03	0.06 + 0.03	0.12 + 0.05	0.6 + 0.08	4.0 + 0.5
	10.00000 V	10 μV						
	100.0000 V	100 μV						
	750.000 V	1.0 mV						
(Temp. Coeff.)/°C ³				0.035 + 0.003	0.005 + 0.003	0.006 + 0.005	0.01 + 0.006	0.03 + 0.01
				3 Hz-10 Hz	10 Hz-3 kHz	3 kHz – 5 kHz		
Current ²	1.000000 A	1.0 μA	90 Day/1 Year	0.30 + 0.04	0.10 + 0.04	0.14 + 0.04		
	3.00000 ¹⁴ A	10 μA		0.35 + 0.06	0.15 + 0.06	0.18 + 0.06		
	(Temp. Coeff.)/°C ³				0.035 + 0.006	0.015 + 0.006	0.015 + 0.006	
				(3 Hz-500 kHz) (333 ms-2 μs)				
Frequency ⁴ and Period	100 mV	0.333 ppm	90 Day/1 Year	80 ppm + 0.333 ppm (SLOW, 1s gate)				
	to	3.33 ppm		80 ppm + 3.33 ppm (MED, 100ms gate)				
	750 V	33.3 ppm		80 ppm + 33.3 ppm (FAST, 10ms gate)				

Additional Uncertainty ±(% of reading)

Low Frequency Uncertainty	MED	FAST
20Hz - 30Hz	0.3	—
30Hz - 50Hz	0	—
50Hz - 100Hz	0	1.0
100Hz - 200Hz	0	0.18
200Hz - 300Hz	0	0.10
> 300Hz	0	0

CREST FACTOR ⁵ :	1-2	2-3	3-4
Additional Uncertainty:	0.05	0.15	0.30

AC MEASUREMENT CHARACTERISTICS

AC Volts

MEASUREMENT METHOD: AC-coupled, True RMS.

INPUT IMPEDANCE: 1MΩ ±2% // by <100pF.

INPUT PROTECTION: 1000Vp or 400VDC, 300Vrms with 7702 module.

AC Current

MEASUREMENT METHOD: AC-coupled, True RMS.

SHUNT RESISTANCE: 0.1Ω.

BURDEN VOLTAGE: 1A <0.3Vrms, 3A <1Vrms. Add 1Vrms when used with 7702 modules.

INPUT PROTECTION: 3A, 250V fuse.

Frequency and Period

MEASUREMENT METHOD: Reciprocal Counting technique.

GATE TIME: SLOW 1s, MED 100ms, and FAST 10ms.

AC General

AC CMRR⁶: 70dB.

MAXIMUM CREST FACTOR: 5 at full-scale.

VOLT HERTZ PRODUCT: ≤ 8 × 10⁷.

AC OPERATING CHARACTERISTICS⁷

60Hz (50Hz) Operation

Function	Digits	Readings/s	Rate	Bandwidth
ACV, ACI	6.5 ⁸	2s/Reading	SLOW	3 Hz-300kHz
	6.5 ⁸	1.4 (1.1)	MED	30 Hz-300kHz
	6.5 ⁹	4.8 (4)	MED	30 Hz-300kHz
	6.5 ⁹	35 (28)	FAST	300 Hz-300kHz
Frequency, Period	6.5	1 (1)	SLOW	3 Hz-300kHz
	5.5	9 (9)	MED	30 Hz-300kHz
	4.5	35 (35)	FAST	300 Hz-300kHz
	4.5 ¹⁰	65 (65)	FAST	300 Hz-300kHz

2790 SourceMeter[®] Switch System Specifications

MAINFRAME FUNCTION SPECIFICATION

AC System Speeds^{7, 11}

RANGE CHANGES¹²: 4/s (3/s).

FUNCTION CHANGES¹²: 4/s (3/s).

AUTORANGE TIME: < 3s.

ASCII READINGS TO RS-232 (19.2k baud): 50/s.

MAX. INTERNAL TRIGGER RATE: 300/s.

MAX. EXTERNAL TRIGGER RATE: 250/s.

AC Notes

- ¹ 20% overrange except on 750V and 3A.
- ² Specifications are for SLOW mode and sine wave inputs >5% of range. SLOW and MED are multi-sample A/D conversions. FAST is DETector: BANDwidth 300 with nPLC = 1.0.
- ³ Applies to 0°–18°C and 28°–40°C.
- ⁴ Specifications are for square wave inputs only. Input signal must be >10% of ACV range. If input is <20mV on the 100mV range then the frequency must be >10Hz.
- ⁵ Applies to non-sine waves >5Hz and <500Hz. (Guaranteed by design for Crest Factors >4.3)
- ⁶ For 1kΩ unbalance in LO lead.
- ⁷ Speeds are for 60Hz (50Hz) operation using factory defaults operating conditions (*RST). Autorange off, Display off, Limits off, Trigger delay=0. Includes measurement and binary data transfer out GPIB.
- ⁸ 0.01% of step settling error. Trigger delay = 400ms.
- ⁹ Trigger delay = 0.
- ¹⁰ Sample count = 1024.
- ¹¹ DETector: BANDwidth 300 with nPLC = 0.01.
- ¹² Maximum useful limit with trigger delay = 175ms.
- ¹³ Typical uncertainties. Typical represents two sigma or 95% of manufactured units measure < 0.35% of reading and three sigma 99.7% < 1.06% of reading.
- ¹⁴ For signal levels >2.2A, add additional 0.4% to “of reading” uncertainty.

Internal Scanner Speeds:

Into and Out of Memory to GPIB¹

7702 Scanning DCV: 60/s

Internal Scanner Speed Notes:

- ¹ Speeds are 60Hz or 50Hz operation using factory default conditions (*RST). NPLC = 0.01. Auto Zero off, Auto Range off, and Display off. Sample count = 1024. Includes measurement and binary data transfer out GPIB.

GENERAL SPECIFICATIONS

POWER SUPPLY: 100V / 120V / 220V / 240V.

LINE FREQUENCY: 50Hz to 60Hz and 400Hz, automatically sensed at power-up.

POWER CONSUMPTION: 28VA.

OPERATING ENVIRONMENT: Specified for 0°C to 50°C. Specified to 80% R.H. at 35°C. Altitude up to 2000 meters.

STORAGE ENVIRONMENT: -40°C to 70°C.

BATTERY: Lithium battery-backed memory, 3 years @ 23°C.

WARRANTY: 1 year.

EMC: Conforms to European Union Directive 89/336/EEC EN61326-1.

SAFETY: Conforms to European Union Directive 73/23/EEC EN61010-1, CAT I.

VIBRATION: MIL-PRF-28800F Class 3, Random.

WARM-UP: 2 hours to rated accuracy.

DIMENSIONS:

Rack Mounting: 89mm high × 213mm wide × 370mm deep (3.5 in. × 8.375 in. × 14.563 in.).

Bench Configuration (with handle and feet): 104mm high × 238mm wide × 370mm deep (4.125 in. × 9.375 in. × 14.563 in.).

SHIPPING WEIGHT: 6.5kg (14 lbs).

DIGITAL I/O: 2 inputs, 1 for triggering and 1 for hardware interlock. 5 outputs, 4 for Reading Limits and 1 for Master Limit. Outputs are TTL compatible or can sink 250mA, diode clamped to 33V.

EARTH ISOLATION: 500V_{peak}, >10GΩ and <150pF any terminal to chassis.

TRIGGERING AND MEMORY:

Window Filter Sensitivity: 0.01%, 0.1%, 1%, 10%, or Full-scale of range (none).

Reading Hold Sensitivity: 0.01%, 0.1%, 1%, or 10% of reading.

Trigger Delay: 0 to 99 hrs (1ms step size).

External Trigger Delay: <2ms.

External Trigger Jitter: <1ms.

Memory Size: 55,000 readings.

MATH FUNCTIONS: Rel, Min/Max/Average/Std Dev/Peak-to-Peak (of stored reading), Limit Test, %, mX + b and m(1/X) + b with user defined units displayed.

REMOTE INTERFACE:

GPIB (IEEE-488.2) and RS-232C.

SCPI (Standard Commands for Programmable Instruments)

ACCESSORIES SUPPLIED: User Manual and Reference Manual, Screw Driver.

MODULES SUPPORTED: Models 7751, 7752, and 7702.

Ohms specification calculations (7751/7752/7753)

Ohms specifications for the 7751/7752/7753 module provide the ohms accuracy and temperature coefficient data for specific I-source and V-source output values. The following formulas can be used to determine the ohms specification for any valid I-source or V-source output setting not published in the specification sheet.

Ohms accuracy and temperature coefficient are specified as percent of reading plus an ohms offset.

7751/7752/7753 I-source

Low ohms specifications using the I-source of the 7751/7752/7753 are provided for the following current output settings: 50mA, 20mA, 10mA, and 1mA (dry circuit ohms). Use the following formulas for other I-source settings:

NOTE The following formulas are only valid when using 1VDC range of the Model 2790 DMM. When using the *SlxOhms* math calculation, the IV range is selected automatically.

Ohms accuracy

$$\% \text{ of reading} = (0.07 + 1/I_{\text{SOURCE}}) \%$$

$$\text{Ohms offset} = (0.03/I_{\text{SOURCE}}) \Omega$$

where; I_{SOURCE} is the current output setting in mA

Example – Determine ohms accuracy for an I-source setting of 30mA:

$$\begin{aligned} \% \text{ of reading} &= (0.07 + 1/30) \% \\ &= (0.07 + 0.03) \% \\ &= 0.10\% \end{aligned}$$

$$\begin{aligned} \text{Ohms offset} &= (0.03/30) \Omega \\ &= 1\text{m}\Omega \end{aligned}$$

$$\text{Ohms accuracy (30mA)} = 0.10\% + 1\text{m}\Omega$$

Ohms temperature coefficient

$$\text{TC \% of reading} = (0.001 + 0.025/I_{\text{SOURCE}}) \% / ^\circ\text{C}$$

$$\text{TC ohms offset} = (0.001/I_{\text{SOURCE}}) \Omega / ^\circ\text{C}$$

where; I_{SOURCE} is the current output setting in mA

Example – Determine temperature coefficient for an I-source setting of 30mA:

$$\begin{aligned} \text{\% of reading} &= (0.001 + 0.025/30) \% / ^\circ\text{C} \\ &= (0.001 + 0.00083) \% \\ &= 0.00183\% / ^\circ\text{C} \end{aligned}$$

$$\begin{aligned} \text{Ohms offset} &= (0.001/30) \Omega / ^\circ\text{C} \\ &= 0.033\text{m}\Omega / ^\circ\text{C} \end{aligned}$$

$$\text{Ohms temperature coefficient (30mA)} = (0.00183\% + 0.033\text{m}\Omega) / ^\circ\text{C}$$

7751/7753 V-source

High ohms specifications using the V-source of the 7751/7753 are provided for the 500V and 50V settings. Use the following formulas for other V-source settings:

For measurements $1\text{M}\Omega$ to $10\text{M}\Omega$

Ohms accuracy

$$\text{\% of reading} = (1.1 + 15/V_{\text{SOURCE}}) \%$$

$$\text{Ohms offset} = 20\text{k}\Omega$$

where; V_{SOURCE} is the voltage output setting in volts

Example – Determine ohms accuracy for a V-source setting of 100V:

$$\begin{aligned} \text{\% of reading} &= (1.1 + 15/100) \% \\ &= (1.1 + 0.15) \% \\ &= 1.25\% \end{aligned}$$

$$\text{Ohms accuracy (100V)} = 1.25\% + 20\text{k}\Omega$$

Ohms temperature coefficient

$$\text{TC \% of reading} = (0.02 + 1/V_{\text{SOURCE}}) \% / ^\circ\text{C}$$

$$\text{TC ohms offset} = 200\Omega / ^\circ\text{C}$$

where; V_{SOURCE} is the voltage output setting in volts

Example – Determine temperature coefficient for a V-source setting of 100V:

$$\% \text{ of reading} = (0.02 + 1/100) \% / ^\circ\text{C}$$

$$= (0.02 + 0.01) \% / ^\circ\text{C}$$

$$= 0.03\% / ^\circ\text{C}$$

$$\text{Ohms temperature coefficient (100V)} = (0.03\% + 200\Omega) / ^\circ\text{C}$$

For measurements 10M Ω to 100M Ω

Ohms accuracy

$$\% \text{ of reading} = (1.1 + 60/V_{\text{SOURCE}}) \%$$

$$\text{Ohms offset} = 20\text{k}\Omega$$

where; V_{SOURCE} is the voltage output setting in volts

Example – Determine ohms accuracy for a V-source setting of 100V:

$$\% \text{ of reading} = (1.1 + 60/100) \%$$

$$= (1.1 + 0.6) \%$$

$$= 1.7\%$$

$$\text{Ohms accuracy (100V)} = 1.7\% + 20\text{k}\Omega$$

Ohms temperature coefficient

$$\text{TC \% of reading} = (0.02 + 6/V_{\text{SOURCE}}) \% / ^\circ\text{C}$$

$$\text{TC ohms offset} = 200\Omega / ^\circ\text{C}$$

where; V_{SOURCE} is the voltage output setting in volts

Example – Determine temperature coefficient for a V-source setting of 100V:

$$\% \text{ of reading} = (0.02 + 6/100) \% / ^\circ\text{C}$$

$$= (0.02 + 0.06) \% / ^\circ\text{C}$$

$$= 0.08\% / ^\circ\text{C}$$

$$\text{Ohms temperature coefficient (100V)} = (0.08\% + 200\Omega) / ^\circ\text{C}$$

For measurements 100M Ω to 1G Ω

Ohms accuracy

$$\% \text{ of reading} = (2 + 510/V_{\text{SOURCE}}) \%$$

$$\text{Ohms offset} = 20\text{k}\Omega$$

where; V_{SOURCE} is the voltage output setting in volts

Example – Determine ohms accuracy for a V-source setting of 100V:

$$\begin{aligned} \% \text{ of reading} &= (2 + 510/100) \% \\ &= (2 + 5.1) \% \\ &= 7.1\% \end{aligned}$$

$$\text{Ohms accuracy (100V)} = 7.1\% + 20\text{k}\Omega$$

Ohms temperature coefficient

$$\text{TC } \% \text{ of reading} = (0.02 + 51/V_{\text{SOURCE}}) \% / ^\circ\text{C}$$

$$\text{TC ohms offset} = 200\Omega / ^\circ\text{C}$$

where; V_{SOURCE} is the voltage output setting in volts

Example – Determine temperature coefficient for a V-source setting of 100V:

$$\begin{aligned} \% \text{ of reading} &= (0.02 + 51/100) \% / ^\circ\text{C} \\ &= (0.02 + 0.51) \% / ^\circ\text{C} \\ &= 0.53\% / ^\circ\text{C} \end{aligned}$$

$$\text{Ohms temperature coefficient (100V)} = (0.53\% + 200\Omega) / ^\circ\text{C}$$

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